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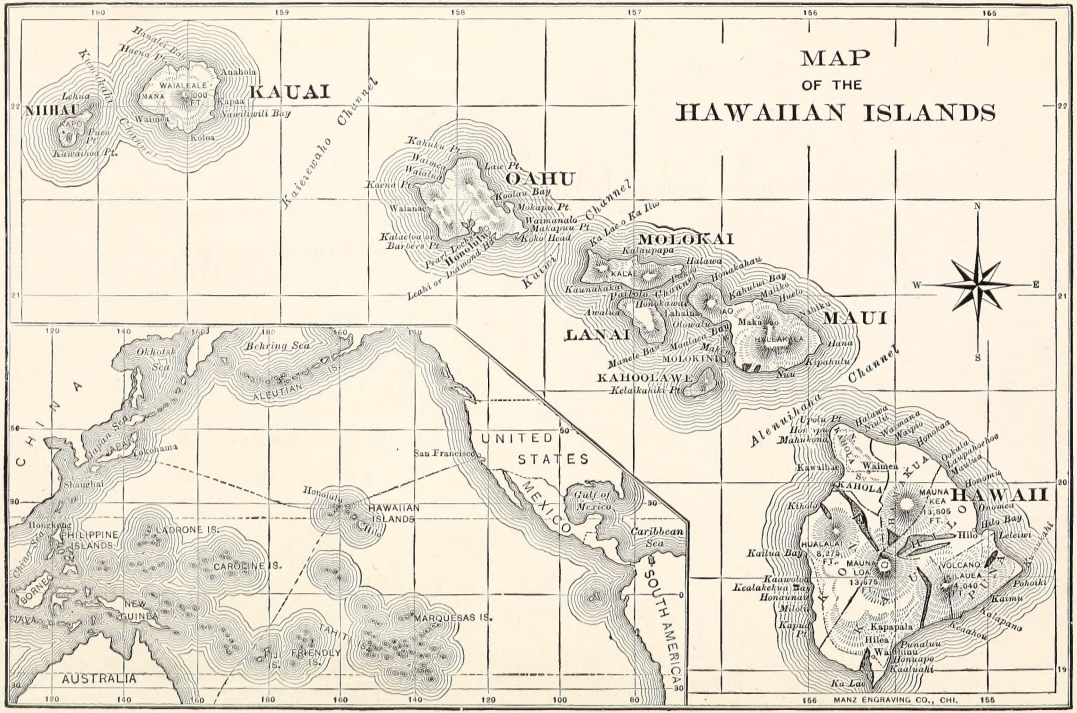

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PLATE I.

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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 93.
L. O. HOWARD, Entomologist and Chief of Bureau.

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THE SUGAR-CANE INSECTS OF HAWAII.

U. S. Department of Agriculture,
Washington, D. C.

BY

D. L. VAN DINE,
Special Field Agent.

ISSUED JUNE 15, 1911.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., December 22, 1910.

Sir: I have the honor to transmit herewith for publication a manuscript entitled "The Sugar-Cane Insects of Hawaii," by Mr. D. L. Van Dine, recently a special agent of this Bureau, and for several years entomologist of the Hawaii Agricultural Experiment Station. The manuscript includes a discussion of the present status of the sugar industry of the Hawaiian Islands and treats of the principal insect enemies to this important industry, which is rapidly assuming large proportions in our Southern States owing to the increased acreage which is being planted to cane. I would recommend its publication as Bulletin No. 93 of the Bureau of Entomology.

Respectfully,

L. O. Howard,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

The acreage devoted to sugar-cane culture in the southern United States has increased rapidly in recent years. Some of the cotton lands, abandoned because of the depredations of the cotton boll weevil, are being planted to cane. New lands are being planted to the crop in the Rio Grande valley and in the reclaimed areas in the lower Mississippi valley. It is stated that quite an area of land in process of reclamation in the State of Florida will be planted to sugar cane. It is desirable that the experience obtained through investigations of insects injurious to sugar cane in the Hawaiian Islands be placed at the disposal of the planters in our Southern States in order that the sugar industry in those States may receive practical benefit therefrom.

The Hawaiian planters are well provided with expert advice and have at hand numerous reports dealing with the subject, which latter, unfortunately, are not available for general distribution. This report is written primarily, therefore, for the information of our mainland planters.

Acknowledgment should be made of the courtesies extended to the writer by the members of the entomological staff of the Hawaiian Sugar Planters' Association Experiment Station during his return visit to the Hawaiian Islands in March and April, 1909.

D. L. Van Dine.

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THE SUGAR-CANE INSECTS OF HAWAII.

LOCATION AND CLIMATE OF THE HAWAIIAN ISLANDS.

The mid-Pacific Territory of Hawaii (see Plate I) is situated 2,100 miles to the southwest from San Francisco, the California coast being the nearest continental area. The islands are separated by channels varying from 20 to 58 miles in width. The 8 inhabitable islands, Hawaii, Maui, Oahu, Kauai, Molokai, Lanai, Kahoolawe, and Niihau, lie between 18° 54′ and 22° 15′ north latitude; that is, the northern limit of the islands is just within the Tropics. The climate of the entire group is, however, only subtropical, due largely to the prevailing northeasterly trade winds, the cool ocean currents from the north, and the relatively low humidity. The temperature varies according to the altitude and the location of the land as regards the higher mountains. The formation of the islands is of recent volcanic nature, with the exception of the low-lying coastal plains, which are of coral origin.

The annual maximum temperature ranges from 88° to 90° F., while the annual minimum temperature recorded ranges from 52° to 58° F. A temperature of 29° F. has been recorded at an altitude of 6,685 feet, and freezing temperatures are of frequent occurrence at these high altitudes. The rainfall varies in amount with the locality. Places within a few miles of each other are known to differ more than 100 inches in average annual rainfall. The sides of the islands exposed to the northeast trade winds have abundant rains, while the opposite sides have little and some localities hardly any.

The soils of the islands are exceedingly fertile and when properly cultivated yield abundant crops.

THE SUGAR INDUSTRY IN HAWAII.

The production of sugar is the leading industry in the Hawaiian Islands. Sugar cane is grown on four of the islands. The island of Hawaii has the largest acreage devoted to cane, Oahu, Maui, and Kauai coming next in importance in the order named. There are more than 200,000 acres planted to cane in the islands. In 1908 521,000 tons of raw sugar were produced, having a value of more than $40,000,000. The average yield of sugar per acre is 4½ tons.

The plant crop is taken off 20 to 22 months from the time of planting, and the first ratoon or stubble is harvested 18 to 20 months later. The second ratoon usually goes 18 months again before it is ground. Sometimes a "short ratoon" crop is made, in which case the cane runs about 14 months. The time given for growth depends on the maturity of the cane, which in turn is governed by the location and altitude of the land. To some extent also the time of harvest is governed by the labor supply, factory conveniences for taking off and grinding the crop, and the need of land for planting.

The sugar industry in Hawaii was placed on a basis to insure its becoming the leading industry by the reciprocity treaty of 1876 between the United States and the Hawaiian Government, the latter at that time being an independent monarchy. The effect of this treaty in removing the duty on raw sugar exported to the United States was to increase American influence in the islands and to strengthen the commercial relations between the two countries. A second great factor in the development of the sugar industry was the annexation of the islands as a Territory of the United States by an act of Congress passed July 7, 1898, by mutual agreement between the two countries, Hawaii at that time having overthrown the monarchy and become a republic. Annexation insured a free and protected market to the sugar output of the islands and gave confidence for the investment of capital. This is of prime importance, as the production of sugar in the islands is on a corporation basis and any disturbance in the market is felt at once by every plantation in the Territory.

Fundamental factors that have attended the development of the sugar industry are the equable climate of the islands, the natural productiveness of the soil, the resources of water for irrigation purposes, and the immunity from the more serious depredations by insects and diseases that retard the development of agricultural resources in less fortunate parts of the world. Further, there is to be found in Hawaii a class of progressive business men who have developed immense irrigation schemes, made use of the most modern agricultural and factory machinery, inaugurated advanced methods of cultivation, fertilization, and irrigation, and united their interests in a cooperative association.

This organization, the Hawaiian Sugar Planters' Association, has, since April, 1895, maintained a private experiment station, where important researches have been made and valuable results obtained. The work has applied to varieties and seedlings, propagation, cultivation, irrigation, the use of fertilizers, and the manufacture of sugar. These investigations, together with the perfection of factory methods and field machinery, have brought the sugar industry of the islands to the high standard it holds among the sugar-producing countries of the world.

SUGAR-CANE INSECTS.

The advent of a serious pest into the Hawaiian sugar-cane fields, the sugar-cane leafhopper (*Perkinsiella saccharicida* Kirk.), between 1900 and 1902 and the widespread injury of this insect throughout the sugar-cane districts in 1903 led to the establishment of an entomological division in the Sugar Planters' Experiment Station in September, 1904. In this division detailed studies have been made of the species of insects occurring in the Hawaiian cane fields, the investigations relating particularly to the leafhopper and its natural enemies.

Koebele[a] has earlier discussed the sugar-cane insects. Up to the time of the leafhopper invasion the sugar-cane borer ([*Sphenophorus*] *Rhabdocnemis obscurus* Boisd.) was the most injurious species. The sugar-cane aphis (*Aphis sacchari* Zehntner), the sugar-cane mealy-bug (*Pseudococcus calceolariæ* Maskell), the leaf-roller (*Omiodes accepta* Butler), cutworms, and certain other pests occurred locally, but up to this time no detailed study of their injury had been made.

An insect enemy of sugar cane has exceptional advantages for development in the Hawaiian Islands. Approximately only one-half the total area is harvested at any one time. Thus the great extent of the plant gives an abundant supply of food, while the system of cropping provides a continuous supply. These conditions, together with the even climate, favor the uninterrupted breeding of any enemy of the plant. A further factor in the undue increase of the cane-feeding insects is the impetus to development arising from the absence of the special parasitic and predaceous enemies of the plant-feeding species. The absence of natural enemies is understood when it is known that the islands are isolated from all continental areas and that the economic plants are introduced forms for which the native flora has made way, carrying with it the endemic species of insects, while the insect enemies of a cultivated plant are of foreign origin, introduced into the islands with their host plant but without their natural enemies. These very facts, together with the almost total absence of secondary parasites as a group and the opportunity of eliminating them when introductions are made, furnish ideal conditions for the introduction and establishment of special parasitic insects. The greatest factor in the successful establishment of a special parasite is the absence of the secondary parasites of which it is the host. One can understand why emphasis has been placed on the use of natural enemies in the control of injurious species in Hawaii and why also greater success has been

[a] Hawaiian Planters' Monthly, vol. 15, no. 12, pp. 590–598, December, 1896; vol. 17, nos. 5 and 6, pp. 208–219 and 258–269, May and June, 1898; vol. 18, no. 12, pp. 576–578, December, 1899; vol. 19, no. 11, pp. 519–524, November, 1900.

attained in Hawaii than in continental regions where investigations of this character are under way. From the above remarks it is apparent that the entomologists of the Hawaiian Sugar Planters' Experiment Station are justified in placing emphasis on this phase of insect control. Indeed, their work has been almost entirely along this line.

THE SUGAR-CANE LEAFHOPPER.

(*Perkinsiella saccharicida* Kirk.)

DISTRIBUTION.

The Hawaiian sugar-cane leafhopper (*Perkinsiella saccharicida* Kirkaldy) was introduced into the islands some time prior to 1900 from Queensland, Australia. The species occurs throughout the sugar-cane areas both in Australia and in Hawaii and has been recorded from Java.[a]

APPEARANCE OF THE LEAFHOPPER IN HAWAIIAN CANE FIELDS.

The first appearance of the leafhopper in Hawaii is recorded by Mr. Albert Koebele in January, 1902.[b] Koebele notes the species under the heading "Leafhopper (Fulgoridæ)," the species at that time not having been described. Regarding its appearance Mr. Koebele says:

> According to Mr. Clark a small homopterous insect appeared upon the sugar cane at the experimental station some twelve months since, affecting the Demerara and Rose Bamboo plants. Its presence is easily seen by the black and dirty appearance of the leaves and more or less red midribs.
>
> The insect lives in company with its larva in large numbers behind leaf sheaths, which it punctures to imbibe the sap of the plant. When mature it is exceedingly active in its habits, springing with suddenness from its resting place at the least disturbance. The eggs are oviposited into the midrib over a large extent, most numerous near the base, in groups of about from four to seven, and large quantities are often present in a single leaf. The surroundings of the sting become red and in advanced stages the whole of the midrib becomes more or less of this color and brownish red.

That the species caused little alarm at this time is indicated by Mr. Koebele's further statement in this same article. He says:

> Should this insect become numerous on any plantation, they could be kept in check by careful and repeated stripping and burning, immediately after, of the leaves containing the eggs. I do not anticipate any serious results from the above insect, which may have been present upon the island for many years.

In May, 1902, Dr. R. C. L. Perkins under the title "Leafhoppers (Fulgoridæ)," in a report to Mr. C. F. Eckart, director of the Hawaiian

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[a] KIRKALDY, G. W.—A note on certain widely distributed leafhoppers. <Science, vol. 26, no. 659, p. 216, 1907.

[b] KOEBELE, A.—Report of the committee on diseases of cane. <Hawaiian Planters' Monthly, vol. 21, no. 1, pp. 20–26, January, 1902.

Sugar Planters' Experiment Station, mentions the doubtful origin and identity of the species.[a] Doctor Perkins again records the insect under the heading "The leaf-hopper of the cane" in December of the same year and says: "This small insect is highly injurious to cane and its destructiveness threatens to exceed that of the cane borer beetle."[b]

In response to repeated requests made to the department the writer was detailed early in May, 1903, to make a report on the pest. On May 11, 1903, specimens were forwarded by the writer to Dr. L. O. Howard, Chief of the Bureau of Entomology, Washington, D. C. Under date of June 1, 1903, Doctor Howard replied that the species was new to science and that there was in press a description of the insect under the name *Perkinsiella saccharicida* by Mr. G. W. Kirkaldy of the British Museum.

DESCRIPTION OF THE LEAFHOPPER.

The species was described by Mr. G. W. Kirkaldy in 1903 and represents a new genus which was named after Dr. R. C. L. Perkins. The description of the genus and species is taken from Mr. Kirkaldy's article in The Entomologist, London, for July, 1903, pages 179–180, and is as follows:

Perkinsiella, gen. nov.

Closely allied to *Arœopus* Spinola, but distinguished by the first segment of the antennæ being distinctly shorter than the second; distinguished from *Dicranotropis* Fieber, to which it bears some resemblance, by the form of the frons, and by the flattened apically dilated first segment of the antennæ. Type, *P. saccharicida* Kirkaldy.

Second segment of antennal peduncle about one-half longer than the first; flagellum about one-third longer than the entire peduncle, first peduncular segment much wider at apex than basally, flattened and explanate; second segment nearly as wide at base as the apex of the first segment [in *Arœopus* it is much narrower, while the first segment is more parallel-sided]. Exterior longitudinal nervure of corium forked near the base, and its exterior branch forked near its middle; interior longitudinal nervure forked near the apex. Membrane with six nervures, the fourth (commencing inwardly) forked; the first area has an incomplete nervure reaching only to the middle. Other characters as in *Arœopus*.

P. saccharicida, sp. nov.

Long-winged form ♂ ♀.—Tegmina elongate, narrow, extending far beyond apex of abdomen, interior half of clavus and corium more or less faintly smoky, a long dark smoky stripe on middle of membrane, three or four of nervures of the latter smoky at apex.

Short-winged form, ♀.—Tegmina reaching only to base of fifth segment, costa more arched, apex more rounded, neuration similar but shortened. Tegmina hyaline, colourless; nervures pale testaceous brownish, with blackish brown non-piligerous dots (in both forms).

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[a] Eckart, C. F.—Precautions to be observed with regard to cane importations. <Report to Hawaiian Sugar Planters' Association, May 9, 1902, p. 5.

[b] Perkins, R. C. L.—Notes on the insects injurious to cane in the Hawaiian Islands. <Hawaiian Planters' Monthly, vol. 21, no. 12, pp. 593–596, December, 1902.

♂. Pallid yellowish testaceous. Abdomen above and beneath black, apical margins and laterally more or less widely pallid. Apical half of first segment and carinate edges of second segment of antennæ, flagellum, basal half of frons (except the pustules) and a cloudy transverse band near the apical margin of the same, longitudinal stripes on femora, coxæ spotted or banded near the base, a large spot on each pleuron, anterior and intermediate tibiæ with two or three annulations, apical segment of tarsi, etc., blackish or brownish. First genital segment large, deeply acute-angularly emarginate above.

♀. Like the male, but abdomen above and beneath stramineous, irregularly speckled with brownish. Ovipositor, etc., blackish. Sheath not extending apically so far as the "scheidenpolster." Long. ♂ ♀ 4½ mill.; to apex of elytra in long-winged form, 6¼ mill.

DISPERSION OF THE LEAFHOPPER.

The spread of the insect over the cane districts of the Hawaiian Islands was apparently very rapid, although it had undoubtedly occurred in the fields unnoticed by the planters for several years. By February, 1903, the species became generally abundant throughout the cane fields of the entire Hawaiian Territory.

The main factor in the distribution of the pest is the habit of the female of depositing her eggs beneath the epidermis of the internodes of the cane stalk. It seems probable that the pest was introduced into the islands and to a great extent distributed over the cane districts in seed cane. In local distribution other factors present themselves. The leafhopper is an insect readily attracted by light at night, as its presence about lamps in the factories and homes on the plantations testifies. Passengers and steamship officers of the interisland steamers have frequently stated to the writer on inquiry that in many instances, especially at night, great numbers of the insects have come aboard in certain ports or when offshore from certain plantation districts. These adults have undoubtedly traveled in this manner from one locality to another so that an uninfested district might easily have become infested by adults flying ashore from a passing steamer previously infested while stopping at or passing by an infested locality. Railway trains have been equally active in the spread of the insect on land.

Another mode of distribution, during the general outbreak of 1903, under conditions of heavy infestation, was the migration of the pest from one locality to another during the daytime. These migrations were observed by many of the planters. The manager of one plantation in the Hamakua district of the island of Hawaii stated to the writer that in the early evening of April 26, 1903, the atmosphere was "thick with hoppers" for a distance of 2 miles and that the "hoppers" were traveling with the prevailing wind, about southwest. Similar migrations, described by the observers as "clouds," were mentioned by other managers.

LIFE HISTORY AND HABITS.

The writer spent two months in the cane fields during the outbreak and in the early part of July, 1903, presented a report to the Hawaiian Sugar Planters' Association on the occurrence and injury of the species. Later an account of these investigations was published, from which a part of the information on the leafhopper presented herewith is taken.[a]

"Leafhopper" is a popular term applied to a certain group of plant-feeding insects of the order Hemiptera. The family Fulgoridæ, to which the Hawaiian sugar-cane leafhopper belongs, is included in this group. Common characteristics of these insects are their peculiar habit of springing or jumping when disturbed; their feeding upon plants by sucking from the tissue the plant juice or sap through a beak or proboscis, a piercing organ by means of which they puncture the epidermal layer of the plant; their incomplete development (that is, the young upon hatching from the eggs resembles the adult, except that it is smaller in size, wingless, and sexually immature and by a gradual process of development acquires the characteristics of the adult); and the fact that their eggs are deposited in the same plant upon which the young and adult appear and feed.

The eggs of the sugar-cane leafhopper (Plate II, figs. 1, 2) are deposited beneath the epidermis of the cane plant in situations along the midrib of the leaves, in the internodes of the stalk, or, in the case of young unstripped cane, in the leaf sheath of the lower leaves. When deposited in the leaves, the eggs are inserted from either side, but usually from the inside, the greater number being in the larger portion of the midrib down toward the leaf sheath. The place of incision is indicated at first by a whitish spot, this being a waxy covering over the opening. The female accomplishes the process of oviposition by puncturing the leaf or stem with her ovipositor, which organ (fig. 1, b) is plainly visible on the lower side of the abdomen, attached to the body at the center behind the last pair of legs and extending backward along the median line of the abdomen, reaching nearly to the end. By the aid of this structure the female pierces the epidermis of the cane stalk and through the one opening forms a cavity or chamber to receive the eggs. The number of eggs deposited in each cavity varies, the writer finding the average to be between four and six. That a single female is responsible for many of these clusters has been verified by the writer by observation. As the growth of the cane continues and the new leaves unfold toward the top of the plant, the infested leaves naturally occupy

[a] Van Dine, D. L.—A sugar-cane leaf-hopper in Hawaii, *Perkinsiella saccharicida*. <Hawaii Agr. Exp. Sta., Honolulu, Bul. 5, pp. 29, figs. 8, 1904.

the lower position on the stalk. The leafhopper, during a heavy infestation, will continue to puncture the midribs of the leaves as rapidly as the leaves unfold. The older egg chambers of the lower leaves are distinguished from the newly formed chambers of the upper leaves by a reddish discoloration.

Under laboratory conditions the writer found that the eggs deposited in cane growing in rearing cages hatched two weeks thereafter. The period of development of the young to the adult required 34 additional days, making the life cycle 48 days in length.

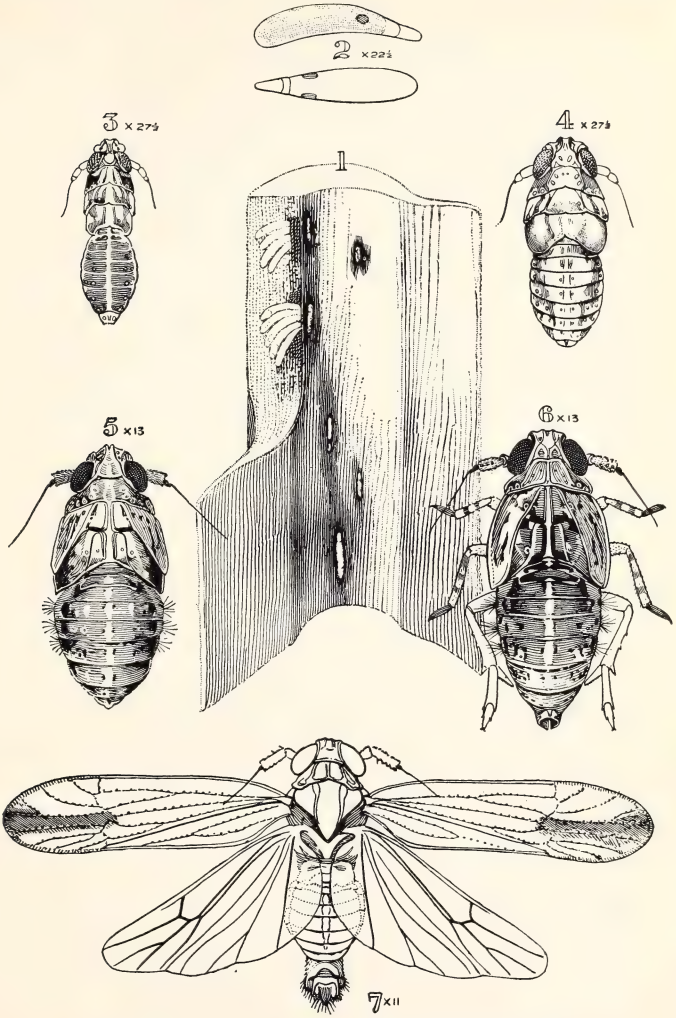
The length of the egg stage, under certain conditions, is much longer than the time given above. Mr. C. F. Eckart, director of the Hawaiian Sugar Planters' Experiment Station, records that hatching continued for 38 days from cane cuttings infested with eggs of the leafhopper.[a]

The fact that the eggs will hatch from cane cuttings during a period of at least 38 days is a very important point to bear in mind in the shipping of infested cane from one locality or country to another. Since practically the only means by which the Hawaiian leafhopper could be introduced into the cane fields of the Southern States is by the shipment of seed cane from New South Wales, Queensland, Java, or Hawaii to this country, the writer would emphasize the necessity of having all introductions made through officials engaged in sugar-cane investigations.

On issuing from the cavity, or chamber, the young, newly hatched leafhoppers appear at first small, slim, wingless nymphs, almost transparent. During the process of hatching or emerging from the egg chamber the insects slowly work their way head first to the surface of the leaf or stalk. The writer found, by timing the operation, that from 8 to 15 minutes were required, during which time the nymphs rest occasionally to unfold and dry their legs. When they become detached from their egg-cases and have emerged to the surface, they are at once active and scatter over the plant to feed, congregating at first down within the sheaths of the upper leaves. In a few hours the body becomes shortened and the outer covering, on exposure to the air, becomes darker in color. The habit of the very young in secluding themselves within the lower sheaths of the leaves renders them quite inconspicuous unless especially sought for. They may become very abundant and still remain undetected by an ordinary observer until the result of their feeding becomes apparent. (See nymphs, Plate II, figs. 3–6.)

Ordinarily when disturbed the adult leafhopper does not fly but moves off in an odd, sidewise fashion to another part of the leaf, or springs suddenly to another portion of the plant. (See adults, Plate II, fig. 7, and text fig. 1.)

[a] Eckart, C. F.—Report of the Hawaiian Sugar Planters' Association Experiment Station for 1903, Honolulu, 1904, pp. 78–79.



THE SUGAR-CANE LEAFHOPPER (PERKINSIELLA SACCHARICIDA).

Fig. 1.—Egg chambers in midrib of cane leaf, slightly enlarged. Fig. 2.—Eggs, greatly enlarged. Fig. 3.—First-stage nymph. Fig. 4.—Second-stage nymph. Fig. 5.—Third-stage nymph. Fig. 6.—Fourth-stage nymph. Fig. 7.—Adult male. (After Kirkaldy.)

SYMPTOMS OF LEAFHOPPER INJURY.

The presence of the pest on the plantations was noticed first by the appearance of a sooty black covering on the lower leaves of the cane plant. This black covering became known as smut. It is a fungous growth and finds a medium for development in the transparent, sticky fluid secreted by the leafhoppers during their feeding on the plant. This secretion is commonly known as honeydew.

The black smut or fungous growth in the honeydew secretion of the leafhopper and the red discoloration about the openings to the egg chambers in the midribs of the leaves are the most pronounced symptoms of the work of the leafhopper on cane.

In the case of heavy infestation a further result is the appearance of the plant as a whole. The leaves on which the insects have been feeding develop a yellowish appearance, and as the work of the insects progresses they become dried and resemble the fully matured lower leaves of the plant. This premature death of the leaves is due to the excessive amount of juice extracted for food. As long as the cane plant is able to produce new leaves its life is not actually in danger, the injury being a check to the growth and indicated by the small, shortened joints in the stalk. Leaves thus prematurely ripened do not drop away from the stalk at the junction of the sheath, as is the case under normal conditions, but break and hang down at the junction of the leaf to the sheath, leaving the sheath still wrapped about the stalk. Leaves in such a condition remain green for some time, attached to the sheath by the midrib, and an attempt to strip the cane results in leaving the sheaths still adhering to the stalk and wrapped about it.

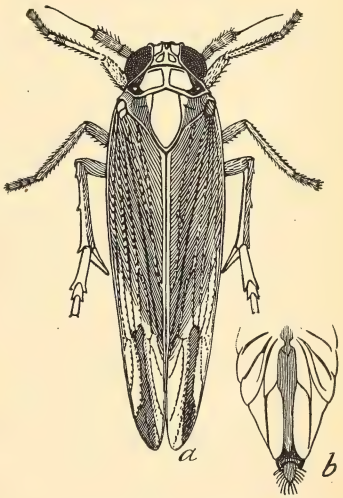


FIG. 1.—The sugar-cane leafhopper (*Perkinsiella saccharicida*): *a*, Adult female, much enlarged; *b*, ovipositor, greatly enlarged. (After Kirkaldy.)

In the last stages of an attack, when the plant is actually overcome by the pest, the young unfolded leaves at the top do not appear to have the vitality to unfold and the "bud" gradually dies out. At this stage the normal growth of the plant ceases. Many plants in

such a condition will then throw out sprouts from the eyes. This is a serious circumstance, since the growth of the sprouts is supported by the stalk, and unless the cane is soon cut and ground the stalk is rendered worthless.

CHARACTER OF INJURY TO THE CANE.

The first injury to the cane plant by the leafhopper occurs through the piercing of the epidermal layer by the ovipositor (fig. 1, *b*) of the female and the later rupturing of the tissue of the plant on the hatching of the young. This injury to the tissue in itself is not serious, but the many openings in the leaves and stalks allow excessive evaporation to occur. Through these wounds various diseases may also gain entrance to the tissues of the plant, carried thereto by the leafhoppers themselves in flying from infested to noninfested plants, or by other insects, particularly certain flies, which frequent the cane plant.

The most serious injury to the plant is the drain upon its vitality caused by the young leafhoppers in feeding. The structure of the mouthparts of the leafhopper has been mentioned; that is, a piercing organ, which is inserted through the outer covering of the tissue, by means of which the insect sucks the juice or sap from within. The amount extracted in this manner by any particular individual is small and of little consequence, but the result of a myriad of individuals working constantly in this manner upon a plant is readily conceived to be serious in its consequences. The leafhopper in feeding upon the cane plant extracts therefrom an amount of juice greatly in excess of its own needs for development. This excess is excreted from the body of the insect upon the cane plant in the form of a sweet, sticky substance, known as honeydew. It is in this substance that the black smut develops.

The sooty covering or smut of the leaves referred to is a superficial fungus which bears a close resemblance to the fungi of the genus Sphæronema. The writer was informed by Dr. A. F. Woods, at that time Pathologist of the United States Department of Agriculture, that this fungus may be responsible for the dying back of canes which followed heavy leafhopper infestation. It is believed, however, that in the cane the smut affects the plant only by preventing the assimilation of the elements taken up by the plant from the soil as food, in cutting off the rays of direct sunlight, and also in closing the stomata of the leaves, preventing the entrance and escape of carbon dioxid and oxygen, respectively. In damp localities another fungus was taken in company with the smut, and was determined by Dr. Woods as a species of the genus Hypochnus. The resulting injury to the plant from the leafhopper attack is also complicated by

the presence of the pineapple disease of sugar cane (*Thielaviopsis ethaceticus*) and the rind disease (*Melanconium sacchari*). The latter species, it is believed, gains entrance to the tissue of the plant through the wounds made by the leafhopper.

EXTENT OF INJURY.

It was estimated that the leafhopper caused a loss of $3,000,000 to the planters of Hawaii during 1903 and 1904.[a] In the writer's opinion this loss can not be attributed entirely to the leafhopper injury. Other species of insects and certain diseases were implicated. The leafhopper was directly responsible for the larger percentage of loss and indirectly responsible for the unusual development of certain diseases.

In speaking of the rind disease of sugar cane in Hawaii in 1907 Mr. L. Lewton-Brain says:[b]

> To bring before you the actual extent of the loss that the rind disease is now causing in your cane fields, I take the following fact obtained by Doctor Cobb from actual counts in the field. In one case the cane left on the ground represented about one ton of sugar to the acre. That is to say, that if the cane left on the field had been sound cane that portion of it left on an acre would produce about a ton of sugar. The area counted over, in this particular case, was representative of 200 acres.
>
> A few years ago, when the leaf-hopper was at the height of its glory in reducing the vigour and vitality of your canes, these figures would have been much higher. I have been assured that, at that time, there were acres and acres of cane to be seen on which the majority of the sticks had been ruined by rind disease.

Apart from the direct and indirect injury of the leafhopper (*Perkinsiella saccharicida* Kirk.), the sugar-cane borer (*Sphenophorus obscurus* Boisd.), the sugar-cane leaf-roller (*Omiodes accepta* Butler), and other minor pests contributed to the loss sustained.

The explanation of the undue increase on the part of the leafhopper is made clear when it is known that up to the time of the leafhopper invasion the sugar plantations had been particularly free from serious attacks of insect and disease pests. The planters were, therefore, unacquainted with the insect life to be found in their cane fields. They did not know the source or nature of the leafhopper attack and had at hand no general knowledge of insect warfare. The injury of the leafhopper, combined with that of the other species mentioned, and the complications arising through the development of certain diseases gave the leafhopper a favorable opportunity to develop great numbers in those localities where climatic influences or soil conditions were unfavorable to the sugar cane or where a deteriorated condition of the cane varieties prevailed.

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[a] Report Governor of Hawaii for fiscal year 1907, p. 22.

[b] LEWTON-BRAIN, L.—Rind Disease of the Sugar-Cane. <Hawaiian Sugar Planters' Exp. Sta., Div. Path., Bul. 7, p. 15, 1907.

FACTORS RESPONSIBLE FOR THE OUTBREAK OF 1903.

On those plantations where the outbreak of the leafhoppers became epidemic the writer made careful observations to determine, if possible, the conditions of season, soil, varieties, or methods of cultivation which might have contributed to the leafhopper development. Some of these conditions noted will be mentioned.

(1) The season during which the attack was most serious was not the growing season, and in some localities the weather was most unfavorable for the growth of the cane. In one instance, for example, there were during one month 24 rainy days out of the 30; and since the temperature on a rainy day is some ten degrees lower than on a bright day, and because of the absence of sunshine to carry on the work of assimilation, a less vigorous growth of cane resulted.

(2) The long duration of prevailing high winds.

(3) An impoverished condition of the soil. Certain fields in which the leafhopper was epidemic had been planted continuously to cane for over 20 years. The soil in certain parts of some fields, also, where the leafhopper infestation was greatest was found to be in poor condition because of lack of drainage.

(4) As the rainy season was followed by a long period of dry weather, without the means of irrigation, the cane lacked sufficient moisture to enable it to put forth a vigorous growth. This point was demonstrated on an unirrigated plantation in the district of Kohala, Hawaii. A portion of a field was seriously attacked by the leafhopper during the month of September, 1903, after several months of dry weather. The manager of the plantation, Mr. E. E. Olding, was able to run water into this portion of the field and irrigated the cane four times at intervals of about a week, with the result that the cane, although showing the attack in the smallness of the joints grown during that time, recovered, and when the writer visited the field during the month of November of the same year was, in appearance, not unlike healthy portions of the same field.

(5) The presence of other pests, principally the cane borer (*Sphenophorus obscurus*) and the leaf-roller (*Omiodes accepta*).

(6) The lack of thorough cultivation.

(7) The injury to cane on the makai (seaward) fields by the salt spray or the check to the cane by the cold on the mauka (mountainward) fields.

(8) The deterioration of varieties.

(9) The complications due to the presence of certain diseases.

THE LEAFHOPPER AND BEEKEEPING.

An interesting condition of affairs arising from the leafhopper attack on sugar cane is the collection of the honeydew by honey bees. The increase in the production of Hawaiian honey of recent years

corresponds with the advent of the sugar-cane leafhopper into the cane fields, and the recent extensive proportions which the bee-keeping business in the islands is assuming is in the vicinity of the immense areas of land given to cane culture.[a] (See fig. 2.)

The principal source of floral honey in the islands is the flowers of the algeroba (*Prosopis juliflora*). The total production of this floral honey does not exceed 600 tons. The output of honey for 1910 in the islands exceeds 1,000 tons, and the remaining 400 tons consists almost entirely of the product gathered from the honeydew of the sugar-cane leafhopper. Some 100 tons of this forms a typical

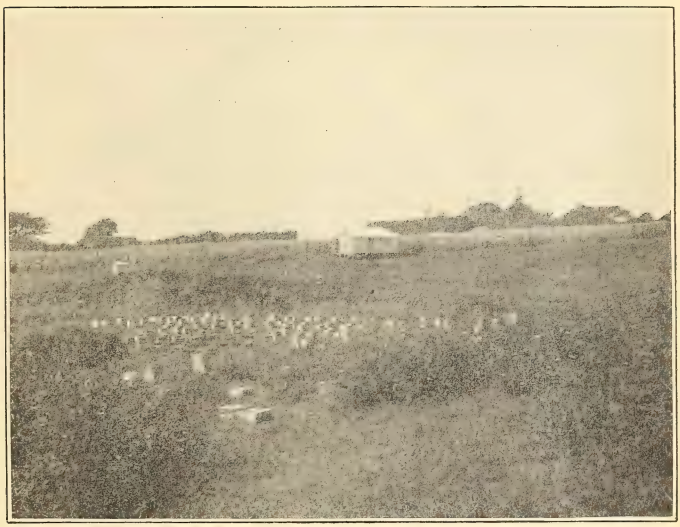

FIG. 2.—An apiary near a sugar-cane field. (From Phillips.)

honeydew honey, the remaining amount consisting of natural blends of these two types.

Honeydew honey from the sugar-cane leafhopper is noncrystallizable and usually of a very dark color. The aroma is very similar to that of molasses and the taste insipid. The product is abnormally high in ash, the amount ranging from 1 to 2 per cent, and it has a decided right-handed polarization, while the floral or algeroba honey is low in ash and has a left-handed rotation, which is

[a] VAN DINE, D. L.—The Source and Characteristics of Hawaiian Honeys. <Hawaii Agr. Exp. Sta., Bul. 17, Pt. I, pp. 1–12, 1908.

PHILLIPS, E. F.—A brief survey of Hawaiian Bee Keeping. <U. S. Dept. Agr., Bur. Ent., Bul. 75, Pt. V, Jan. 19, 1909.

characteristic of all floral honeys. The larger amount of honeydew is obtained from the insects on the young plant cane, for there the leafhoppers are more abundant. The amount of honeydew gathered depends on the maturity of the cane and the amount of rain which washes the secretion from the leaves.

CONTROL OF THE LEAFHOPPER.

Direct Measures.

Insecticides.—Those familiar with the culture of sugar cane will readily understand the difficulty of getting in and through the fields after the cane obtains any height. This difficulty renders the use of insecticides as a remedy unpractical. In Hawaii such a method becomes still more difficult because of the prevailing slope of the cane lands and the manner in which the fields in many districts are laid out for purposes of irrigation. The feeding habits of the leafhopper are such that a contact poison or irritant would be necessary for its destruction, and the activity of the leafhoppers—that is, the suddenness with which they disperse at the least disturbance—still further prevents the successful application of a contact insecticide. Then, too, the cane fields of Hawaii are subject to prevailing winds, which greatly interfere with the use of any substance in the form of a spray. In the face of the above difficulties the writer attempted the destruction of the leafhopper by direct measures and found that an application of kerosene emulsion applied in the shape of a finely divided stream with considerable force was capable of killing only a small percentage. A mixture of lime and caustic soda was also applied, with negative results. Lime, prepared by reducing fresh stone lime to a powder by the use of solutions of copper sulphate and caustic soda, was applied as a dust on cloudy days, or just after showers, and while in comparison to spraying a much larger area was covered, and the dust came in contact with a large percentage of the leafhoppers, no appreciable beneficial results were observed.

Collection by nets.—Ordinary sweeping nets supplied with short handles were placed in the hands of the laborers, and the leafhoppers were collected by having the laborers go in a body through adjoining rows and sweep the nets over the cane leaves. The insects collected were dumped from the nets into buckets of water and kerosene at the ends of the rows. While immense numbers were captured in this way, the number collected and the area covered were so small in comparison to the abundance of the leafhoppers and to the extent of the infested area that this measure was also discarded.

Cutting and burning in the infested centers.—The direct measures of control advised by the writer were confined to the cutting down

and burning over of those centers in the fields where the species had become numerous. In this practice it was observed that many of the adults were able to take flight from the burning cane and escape to adjoining fields. However, many adults and all of the unhatched eggs in the leaves and the immature wingless forms were destroyed. The center of infestation was destroyed, and this gave the ratoon crop over these areas a chance under more favorable conditions.

Stripping the leaves.—For agricultural reasons it was a common practice in Hawaii to strip the lower mature leaves from the cane stalk. It was believed at first that this operation would greatly lessen the numbers of the leafhopper by the exposure of the unhatched forms in the leaves of the cane and by removing a place of shelter for the active forms. Observations made during the summer months indicated that stripping was beneficial from the standpoint of the control of the leafhopper. Later observations made during the winter months, however, when growth of the cane practically ceases, showed a very serious condition of affairs, namely, that in heavy infestation the internodes of the stalk of stripped cane contained hundreds of punctures from egg laying, while the internodes of unstripped cane were protected from such injury by the leaf-sheaths.

Burning of trash after harvesting.—The thorough burning of the trash after the cane is harvested is the most effective method practiced for the control of the insects of sugar cane. In the case of the leafhopper many of the adults no doubt take flight, but the destruction to the eggs and immature forms in the trash is enormous. The place where the greatest numbers of the leafhopper were noted in 1903 was on a plantation where the practice of "burning off" had been discontinued for several years, and the manager attributed the unusual increase of the pest to the fact that the trash had not been burned. Both for the leafhopper and the cane borer, burning off has become general once more.

Indirect Measures.

preventive methods.

Selection of varieties of cane for planting.—There was noticeable in general throughout the plantations a marked difference in the power of the different varieties to resist the attack of the leafhopper. While the same variety would vary in different localities as regards growth and resistance, still the difference between any two varieties remained constant. For example, Yellow Caledonia was invariably the more resistant as compared to Rose Bamboo and Lahaina, and while the former was more seriously attacked in some localities than in others, wherever the opportunity offered itself for comparison with the latter, the Yellow Caledonia made the best showing. It is for

the planter to decide whether or not the advantages of one variety over another are offset by the ravages of the leafhopper. If the loss from the leafhopper is greater than the gain in the yield between any two varieties in the absence of the leafhopper, then it is policy to select the more resistant cane.

The Yellow Caledonia (fig. 3) is a hardy cane and the plant makes a vigorous growth. These qualities, together with the showing which the variety made during the leafhopper epidemic, have made the cane a popular variety in the Hawaiian Islands. Mr. C. F. Eckart,

FIG. 3.—Yellow Caledonia sugar cane, a variety which is replacing Lahaina and Rose Bamboo in the Hawaiian Islands. Photograph taken during the leafhopper epidemic of 1903. (Original.)

Director of the Hawaiian Sugar Planters' Experiment Station, reports as follows on this cane:[a]

Probably no subject pertaining to the cultivation of cane in the Hawaiian Islands during recent years has held more interest for the planters, in various localities, than that relating to the introduction and trial of new varieties.

In the Hilo and Hamakua districts, the Lahaina first made way for the Rose Bamboo, and the latter, after a strong stand for many years, *is now being rapidly succeeded by the more vigorous Yellow Caledonia.* This cane with its upright growth and deep rooting propensities has proved a most valuable acquisition in wet and dry localities alike. Growing erect, with a natural tendency to shed its dried leaves, it becomes an admirable cane for rainy districts, where varieties that are prone to fall to the ground and remain in contact with a frequently saturated soil have shown extreme

[a] ECKART, C. F.—Varieties of cane. <Report of the Experiment Station Committee, Hawaiian Sugar Planters' Association, for the year ending September 30, 1904, Appendix IV, p. 31.

sensitiveness. The frequent stripping, required for Lahaina and Rose Bamboo in these wet places, has necessarily added to the cost of cultivation, and the ready manner in which Yellow Caledonia tends to strip itself is no small item in favor of economy. Again the manner in which it keeps down weeds, which were such a menace to its predecessors on the unirrigated plantations, is another strong point in its favor. In dry districts subject to occasional drought, it has amply demonstrated its hardihood over Rose Bamboo, which in turn is more resistant to such unfavorable climatic features than Lahaina. By sending its roots down deep into the soil it draws from a larger reserve supply of water than the older varieties, which are more shallow feeders and which soon feel the effects of a rainless period.

Dr. R. C. L. Perkins reports as follows on the relative immunity of different varieties of cane from leafhopper attack:[a]

It seems certain that some varieties of cane will stand the attack of leaf-hopper better than others. Mr. Eckart, Director of the Hawaiian Sugar Planters' Experiment Station, has furnished me with a list of new varieties of cane (see Appendix, Note II below), grown there, arranged in order, according to the relative injury that each sustained from leaf-hopper.

There may come, however, so severe an attack that no cane can resist it. Thus we have seen plants of "Yellow Caledonia" (at the extreme end of the list) which were of the strongest and most thrifty nature previous to the attack, some entirely destroyed and others very badly injured after a bad outbreak. It is, however, probable that from an attack of hopper which would entirely destroy a field of "Rose Bamboo," for instance, a field of "Yellow Caledonia" might recover.

The following is the note to which Doctor Perkins refers above:

The following list of new varieties (i. e., varieties other than the old standard ones of these islands) of cane at the Hawaiian Planters' Experiment Station has been drawn up for me by Mr. C. F. Eckart, the Director. They are arranged in order, according to the amount of damage sustained from leaf-hopper attack, Queensland 4 suffering most and Yellow Caledonia least:

(1) Queensland 4
(2) Queensland 1
(3) Queensland 8A.
(4) Louisiana Purple
(5) Demerara 95
(6) Gee Gow
(7) Cavengerie
(8) Demerara 74
(9) Yellow Bamboo
(10) Tiboo Merd
(11) Louisiana Striped
(12) Striped Singapore
(13) Big Ribbon
(14) Queensland 7
(15) Demerara 117
(16) White Bamboo
(17) Yellow Caledonia.

Cultural methods on the plantation.—The writer has already mentioned the fact that the epidemic of 1903 began during the winter months, in a wet season, and at a time when the cane was making practically no growth. The centers from which the infestation spread over the cane fields were invariably unfavorable locations for growth. It has been noted in this report that all varieties suffered in these unfavorable locations but that certain varieties made a better showing. The extension of the acreage of one variety in particular,

[a] PERKINS, R. C. L.—The leaf-hopper of the sugar-cane. <Bd. of Agr. and Forestry, Hawaii, Div. Ent., Bul. 1, p. 13, 1903.

Yellow Caledonia, will be a leading factor in preventing another epidemic. One other point was brought home to the Hawaiian planters as a result of the leafhopper epidemic, and that was the importance of intensive cultivation. The grass and weeds must be kept down by cultivation, the low places drained, and the impoverished lands fertilized. Those plantations which were in a high state of cultivation suffered less from the leafhopper attack, and the estates provided with the means of irrigation, in addition, suffered the minimum loss. There is a direct relation between intensive cultivation, fertilization, and irrigation and the amount of insect injury to any crop, showing that these operations are of great value in lessening insect damage.

Diversification of crops.—Sugar cane has been the leading crop in Hawaii since the days when the islands turned from the sandal-wood trade and the whaling fleet as a source of revenue. Some of the lands have been under cultivation to cane continuously for over twenty-five years. The time is at hand when the sugar-cane planters will find it both necessary and more profitable to diversify their crop. Some lands at present require a change from sugar cane, and the lands which are still highly productive will also require such a change as the years go by. When the general practice of inter-cropping cane with other plants does come, it will have a direct bearing on the control of the sugar-cane insects, the leafhopper included. The intermediate crop may be one of value in itself or one to be plowed under for green manure. Since it is not wise to cease the practice of burning off the trash after harvesting the cane, the planters can find no cheaper source of plant food, or no way in which the requisite texture and water-holding capacity of the soil can be more easily obtained than by removing their lands from cane cultivation in regular rotation and planting some nitrogen-gathering plant to be turned under when the land is put back into cane.

Control of the rind disease of sugar cane.—As has been mentioned, leafhopper injury is aggravated by the presence of the rind disease. In a discussion of the rind disease (*Melanconium sacchari*) Dr. N. A. Cobb says:[a]

> According to my observations on thousands of cuttings dug up on some twenty-five plantations a considerable part of the cuttings in some fields fail to grow on account of this disease, which, being present in the cuttings when they are planted, develops sufficiently to prevent germination. This is a difficult thing wholly to avoid by means of inspection of the seed, as the disease is sometimes present in cane that looks sound. It may be suspected to be present in any cane that has been attacked on the stalks by leaf-hopper or by borers. Other wounds that give admission to the rind disease fungus are those made by injudicious stripping, cracks at the bottom of the cane due to the effects of storms, and what are sometimes called "growth cracks."

[a] Cobb, N. A.—Fungus maladies of the sugar cane. <Hawaiian Sugar Planters' Exp. Sta., Div. Path., Bul. 5, p. 107, 1906.

Cane raised specially for seed and not stripped until wanted for planting is more likely to be free from insect punctures, and will therefore be less likely to develop rind disease after planting.

Mr. L. Lewton-Brain in a report on the rind disease thus describes the relation between the leafhopper and the disease: [a]

Under field conditions, of course, the spores gain access to the interior of the plant through natural wounds. Perhaps the most abundant wounds offered for this purpose are leafhopper punctures; even more favorable for the fungus are the tunnels of borers, leading as they do right into the heart of the sugar-containing tissue; other wounds may be made in stripping; in fact, it is a difficult matter to find a stalk of cane without a wound of some sort. The spores are produced in immense numbers on every stick of rotten cane. They are doubtless distributed partly by the wind, though the mucilaginous substance by which they are joined does not favor this; insects are certainly also important distributers of the spores, leafhoppers will get infected and deposit the spores in their punctures, ants will carry them into borer and other wounds in their search for food, flies may also serve the fungus in the same way.

The control of the rind disease of cane on the plantation will be another factor in reducing leafhopper injury. Since the leafhopper can not be exterminated and the punctures from this insect will always occur on a plantation to a greater or less degree, it becomes particularly essential for the planter to eradicate the disease.

On the control of the rind disease, Doctor Cobb has the following on pages 109 and 110 of his report referred to above:

The number of spores of this disease that exist on every plantation is past calculation, and almost inconceivable. This abundance of the spores of the disease tends of course to increase the losses. If there were no spores there could be no rind disease. Anything that can be done to reduce the number of spores will tend to reduce the amount of the disease. Something can certainly be done in this direction. Stalks dead of the disease can be destroyed, and there can be no doubt that in some cases expenditure in this direction will be well repaid. There can be no doubt that the collecting and complete destruction of the stalks on the field would be a paying operation. How to destroy them is the question. The ordinary burning off destroys only a part of these rind disease stalks, leaving the rest untouched or only partially roasted, to go on producing their millions upon millions of spores.

It is the custom on all the Hawaiian plantations to leave on the ground after harvest the sticks of cane that have been attacked by borers or are worthless for other reasons. The reason for this is easy to understand. Such material is unsuitable to the highest efficiency of the mill as an extractor of cane juice. It is also of such a nature that it may interfere with the clarification, evaporation, or crystallization.

Notwithstanding this I think it would be advisable to consider whether this material, which is really a menace to the health of future crops, cannot in some way be run through the mill and burned. This is a practice adopted in some other parts of the world. On Saturday afternoons a special run of the mill is devoted to the milling of such refuse as I have mentioned, the "bagasse" being burned. The juice is allowed to run to waste, being first sterilized by heat.

In Hawaii it is usual to attempt to burn this diseased material, but from careful observation I am certain that this attempt often ends in failure, that is to say the disease that exists in the waste-cane is only partially destroyed.

[a] Lewton-Brain, L.—Rind disease of the sugar cane. <Hawaiian Sugar Planters' Exp. Sta., Div. Path., Bul. 7, p. 21, 1907.

It may be that it would be better, at least from the disease point of view, if the harvesting of the fields were more in the nature of a clean sweep. If the diseased sticks are not too numerous they would not seriously interfere with the working of the mill. The advantage would be that whatever diseased material was thus dealt with would be dealt with in the very best manner, that is, it would be utterly destroyed.

NATURAL ENEMIES.

Species Already Present in the Islands.

Many beneficial species of insects, already present in the islands at the time of the leafhopper invasion, adapted themselves to the leafhopper as a source of food. The following species were noted during 1903:

A ladybird beetle, *Coccinella repanda* Thunb., one of Mr. Koebele's Australian introductions, was particularly abundant in the cane fields and the larva did good work against the young leafhoppers. An enemy of this species, the hymenopterous parasite *Centistes americana* Riley, has found its way to the islands and will no doubt reduce the effectiveness of the ladybird. The writer observed also the ladybird *Platyomus lividigaster* Muls. in the cane fields. A predaceous bug, *Œchalia griseus* Burm., was found in large numbers in the infested cane fields on the Island of Hawaii. The larvæ of two lacewing flies, *Chrysopa microphya* McLachl., and *Anomalochrysa* sp., were observed feeding on the young leafhoppers, the first species being particularly abundant in some localities.

Several species of spiders were abundant in the cane fields and were active enemies of the leafhopper. The writer collected two species, *Tetragnatha mandibulata* Walck. and *Adrastidia nebulosa* Simon. On the writer's advice large numbers of the egg-nests of spiders were collected in the localities where they were abundant and placed in sections where they had not as yet become established in the cane fields.

In the forest above the Kohala district, on the island of Hawaii, the writer found a fungous disease infecting to a great extent the common leafhopper *Siphanta acuta* Walk., a species belonging to the same family as the cane leafhopper. Quantities of this fungus were distributed in the cane fields in the hope that it would infest the cane leafhopper. No striking results were obtained, though diseased cane leafhoppers were found in some of the rainy districts.

Several species of ants were very active about the leafhoppers in the cane fields, the honeydew being an attraction to them.

Doctor Perkins mentions further in his early report a predaceous bug, *Zelus peregrinus* Kirk., and describes as new a hymenopterous parasite of the leafhopper under the name *Ecthrodelphax fairchildii* Perk.[a]

[a] Perkins, R. C. L.—Bd. Comrs. Agr. and Forestry, Hawaii, Div. Ent., Bul. 1, pp. 20–22.

More recently the species of beneficial insects which were already present in the islands when the leafhopper was introduced and which have sought the leafhopper in the cane fields have been reported upon in detail by the entomologists of the Hawaiian Sugar Planters' Experiment Station.[a]

SPECIAL INTRODUCTIONS.

In 1903 Mr. Albert Koebele, after consulting with Dr. L. O. Howard, undertook extensive observations on the American parasites of leafhoppers. In Ohio Mr. Koebele had the assistance of Mr. Otto H. Swezey. A large quantity of living material was collected both in Ohio and in California and shipped to Doctor Perkins at Honolulu. The American material consisted in the main of insects belonging to the hymenopterous family Dryinidæ. The Hawaiian parasite *Ecthrodelphax fairchildii* Perkins is also a member of this family and, at the time of Mr. Koebele's American introductions, was being reared and distributed over the islands by Doctor Perkins. These introductions are discussed by Doctor Perkins in Part I of Bulletin 1, Division of Entomology, Hawaiian Sugar Planters' Experiment Station, 1905.[b]

Mr. Koebele also collected during his American investigations representatives of the order Strepsiptera (Stylopidæ) and a single species of an egg-parasite, *Anagrus columbi* Perk., belonging to the family Mymaridæ.[c]

In the spring of 1904 Messrs. Koebele and Perkins sailed for Australia to continue the search for parasites of the leafhopper. They reached Sydney in May and because of the cold weather which prevailed they proceeded to Brisbane. The results of the work in Australia are thus summarized by Doctor Perkins:[d]

Early in June we arrived at Brisbane, and on the first cane that we saw, a few plants in the public gardens, we at once observed the presence of the cane leaf-hopper. A

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[a] Leafhoppers and their natural enemies. <Hawaiian Sugar Planters' Exp. Sta., Div. Ent., Bul. 1.

PERKINS, R. C. L.—Part I, pp. 1–60, May, 1905. (*Ecthrodelphax fairchildii.*)

PERKINS, R. C. L.—Part IV, pp. 113–157, pls. 5–7, September, 1905. (Pipunculidæ.)

TERRY, F. W.—Part V, pp. 159–181, pls. 8–10, November, 1905. (Forficulidæ, Syrphidæ and Hemerobiidæ.)

SWEZEY, O. H.—Part VII, pp. 207–238, pls. 14–16, December, 1905. (Orthoptera, Coleoptera, and Hemiptera.)

[b] PERKINS, R. C. L.—Leafhoppers and their natural enemies. <Hawaiian Sugar Planters' Exp. Sta., Div. Ent., Bul. 1, Part I, pp. 1–60, May, 1905. (Dryinidæ.)

[c] PERKINS, R. C. L.—Leafhoppers and their natural enemies. <Hawaiian Sugar Planters' Exp. Sta., Div. Ent., Bul. 1, Pt. III, pp. 86–111, pls. 1–4, August, 1905. (Stylopidæ.)

PERKINS, R. C. L.—Leafhoppers and their natural enemies. <Hawaiian Sugar Planters' Exp. Sta., Div. Ent., Bul. 1, Pt. VI, p. 198, November, 1905. (*Anagrus columbi.*)

[d] PERKINS, R. C. L.—Leafhoppers and their natural enemies. <Hawaiian Sugar Planters' Exp. Sta., Div. Ent., Bul. 1, introduction, pp. III, IV, May, 1906.

short stay of about ten days gave ample proof of the existence in Australia of a considerable variety of Hymenopterous parasites of leaf-hoppers, of Dipterous parasites of the genus *Pipunculus*, and of Stylopid parasites of the genus *Elenchus*.

At Bundaberg, about twelve hours by rail north of Brisbane, we spent another ten days in June. Here is an extensive cane district with our leaf-hopper everywhere present, but never in numbers such as we are accustomed to in these islands. In fact we never saw the hoppers nearly as numerous as they are on our least affected plantations. From eggs collected here Mr. Koebele soon bred out specimens of the Mymarid parasites he had felt so confident of finding.

From our observations on the habits of the cane leaf-hopper in these islands, it seemed probable that in tropical Australia this species would be in its greatest numbers in the colder months, so after a brief stay in Bundaberg, we proceeded north to Cairns, which place we reached at the beginning of July. This plan seemed very expedient, for by retreating gradually towards the south, as the hot season advanced, we hoped to prolong the season during which natural enemies for the cane leaf-hopper could be obtained. It appeared likely that effective work could only be done at Cairns for a month or two, since without a reasonably large supply of hoppers, it was evident that the parasites could not be found in sufficient numbers for shipment. This indeed proved to be the case, and by the end of August, leaf-hoppers and their eggs had become so scarce in the cane fields, that we came south again to Bundaberg. At Bundaberg we made a long stay on this occasion, regularly sending off consignments of parasites, until here too, owing partly to the season and partly to the harvesting of the crop, the locality became unprofitable. After a short stay in Brisbane, at the end of the year, I returned to Honolulu, while Mr. Koebele proceeded to Sydney, where his attention was largely given to collecting beneficial insects for pests other than leaf-hopper. On the return journey Mr. Koebele spent one month in Fiji, the enemies of the cane-hopper in those islands being mostly similar to those already found in Australia. A fine consignment of the Chalcid egg-parasite (*Ootetrastichus*) of leaf-hopper was most important, as it enabled us to establish that important species without any doubt.

During January and February, 1906, Mr. F. Muir continued the work in the Fiji Islands begun by Mr. Koebele in the latter part of 1904. He reported as follows concerning the Fijian sugar-cane leaf-hopper and its parasites:[a]

The Fijian sugar-cane leaf-hopper (*Perkinsiella vitiensis*) I found all over the island, but it does no damage, being kept in check by several natural enemies.

The most important of these are the egg-parasites, *Ootetrastichus*, *Anagrus* and *Paranagrus*. The first of these was introduced from Fiji into Hawaii by Mr. Koebele, and the other two appear to me the same as the Queensland species. In some fields as many as 90 % of the hopper eggs were parasitized, but in other fields it was lower. Observations extending over my six months' stay, and made at the various parts of the island visited, show that an average of 85 % of hopper eggs were destroyed by these parasites. These figures are only approximate, as I have to estimate that one Chalcid (*Ootetrastichus*) destroys four hopper eggs, which is a low estimate. This Chalcid is more numerous, and on account of destroying the whole batch of hopper eggs, is of very much higher economic value than the Mymarids.

[a] Muir, F.—Notes on some Fijian insects. <Hawaiian Sugar Planters' Exp. Sta., Div. Ent., Bul. 2, p. 3, November, 1906.

The Australian and Fijian material has been described in detailed reports with elaborate illustrations by Messrs. Perkins, Terry, and Kirkaldy.[a]

Regarding the effectiveness of the various parasites and enemies of the leafhopper, Dr. Perkins says:[b]

If we consider the effectiveness of the four egg-parasites, *Paranagrus optabilis*, *P. perforator*, *Anagrus frequens*, and *Ootetrastichus beatus*, *in areas where all are well established*, we must rate the first-named as *at present* by far the most effective. As I have previously pointed out, this species is capable by itself of destroying about 50 per cent of the cane-hopper's eggs and *Anagrus frequens* and *P. perforator*, extraordinarily numerous as they appear, where seen alone, are but as isolated examples in the crowd, where all are well established in one spot. The *Ootetrastichus* slowly but steadily increases in numbers, and on many plantations I expect that it will ultimately be the most efficient of all parasites. I do not think that it can show its full value till 1908, for each harvesting of the cane crop is necessarily a very great setback to its natural increase. *Anagrus frequens*, under which name are probably more than one species, or at least one or two distinct races of a single species, although it appears at a disadvantage, when in company with *Paranagrus optabilis*, is nevertheless a most abundant parasite. In Part VI of this Bulletin I have compared the habits of the two and need not refer to the matter here, but I may say that as many as eighty or a hundred exit holes of the *Anagrus* have been counted in a single cane-leaf, so that its great utility is unquestionable. *P. perforator*, common in Fiji, attacking eggs of hopper laid in thick stems of grass, more rarely those in cane, will probably gradually wander away from the cane-fields to attack the eggs of native hoppers, that are laid in stems and twigs, as it now chiefly attacks the cane-hopper eggs when these are laid in the stems.

Nor must it be forgotten, what valuable aid these egg-parasites receive in the control of leaf-hopper from other insects parasitic and predaceous, native or introduced. In fact, had there existed previously no restraint to the multiplication of the pest, no

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[a] Hawaiian Sugar Planters' Exp. Sta., Div. Ent.:

PERKINS, R. C. L.—Bul. 1, Pt. I, pp. 1–69, May, 1905 (Dryinidæ).

PERKINS, R. C. L.—Bul. 1, Pt. II, pp. 71–85, figs. 1–3, June, 1905 (Lepidoptera).

PERKINS, R. C. L.—Bul. 1, Pt. III, pp. 86–111, pls. 1–4, August, 1905 (Stylopidæ).

PERKINS, R. C. L.—Bul. 1, Pt. IV, pp. 113–157, pls. 5–7, September, 1905 (Pipunculidæ).

TERRY, F. W.—Bul. 1, Pt. V, pp. 177–179, November, 1905 (Syrphidæ).

PERKINS, R. C. L.—Bul. 1, Pt. VI, pp. 183–205, pls. 11–13, November, 1905 (Mymaridæ, Platygasteridæ).

PERKINS, R. C. L.—Bul. 1, Pt. VIII, pp. 239–267, pls. 18–20, January, 1906 (Hymenoptera).

KIRKALDY, G. W.—Bul. 1, Pt. IX, pp. 269–479, pls. 21–32, February, 1906 (Leafhopper).

PERKINS, R. C. L.—Bul. 1, Pt. X, pp. 481–499, pls. 33–38, March, 1906 (Hymenoptera, Diptera).

KIRKALDY, G. W.—Bul. 3, pp. 1–186, pls. 1–20, September, 1907 (Leafhoppers, Supplement).

PERKINS, R. C. L.—Bul. 4, pp. 1–59, May, 1907 (Parasites of Leafhoppers).

[b] PERKINS, R. C. L.—Leaf-hoppers and their natural enemies. <Hawaiian Sugar Planters' Exp. Sta., Div. Ent., Bul. 1, introduction, pp. xv–xvii, May, 1906.

one who has paid the least attention to such matters can doubt that it would some time since have become impossible to raise any crop of sugar cane in the islands. The reason why these natural enemies have not alone got the upper hand of the hopper is due to various causes. In the first place, a number of the parasites such as the Dryinid *Ecthrodelphax fairchildii* and the parasitic flies of the genus *Pipunculus* are of local occurrence, and in many places cannot (for climatic or other unknown reasons) maintain their existence. This was well shown by the behavior of the first-named, which was distributed in thousands by the entomologists and the Plantation managers themselves to all the districts in the islands, but in many places did not thrive. Such, too, is the case with the predaceous black earwig (*Chelisoches morio*) which, a natural immigrant to the islands and no doubt acclimatised centuries ago, is found on comparatively few plantations. Other natural enemies are themselves periodically decimated by parasites, as is the case with the introduced green cricket (*Xiphidium varipenne*), which has its own egg-parasite (*Paraphelinus*). Other enemies like the common lady-bird (*Coccinella repanda*) introduced by Koebele years ago for other purposes, prey on young leaf-hoppers, in default of more favorite food, and this valuable predator too is itself subject to parasitic attack by the common Braconid (*Centistes*). At present the whole number of parasites and predaceous insects that attack cane leaf-hopper to such an extent as to render their services worth noting is considerable, as the following summary shows.

The most valuable are the four egg-parasites, which there is every reason to hope will become still more effective with reasonable time, one (*Ootetrastichus*) having as yet had no chance to show its full effectiveness.

The two Pipunculus flies (*Pipunculus juvator* and *terryi*) are restricted to certain localities and are native species, which have transferred their attacks from native Delphacids to the cane leaf-hopper.

The ubiquitous lady-bird (*Coccinella repanda*) is valuable as a destroyer of leaf-hopper, though originally imported by Koebele to destroy Aphis. It is hoped that other lady-birds, especially *Verania strigula,* may become established and do good work, as in Australia and Fiji, whence they were imported.

The earwig *Chelisoches morio* is a local species, but no doubt useful where it exists in numbers.

The green cricket (*Xiphidium varipenne*) is very valuable, but is most unfortunately heavily attacked at certain seasons by an egg-parasite.

The Dryinid *Ecthrodelphax fairchildii* is locally valuable. At certain seasons in suitable, but limited, localities, it destroys a considerable percentage of hoppers. Its services are underestimated because for a large part of the year it lies as a dormant larva in the cocoon, and parasitized hoppers at such a time are naturally hardly to be found.

There are many other natural enemies of more or less importance, e. g. the various predaceous Hemiptera, and the several lace-wing flies (*Chrysopinæ*).

In addition to these insect enemies, we must mention the two fungous diseases of hoppers (amounting locally and at certain seasons to epidemics) which, long previously known to kill the native leaf-hoppers, have become transferred to the introduced pest. We also found one or more fungous diseases attacking leaf-hopper eggs in Fiji and Australia in all localities. With material imported from these countries, I easily infected eggs of the cane leaf-hopper under cover, and subsequently established the fungus at large in the field. As it was most probable that parasitized and healthy hopper eggs would be affected alike by the disease, and consequently many of the egg-parasites would be destroyed, it became a subject of discussion whether we should attempt to establish the fungus or not. As, however, throughout Australia, the fungus and parasite both attacked the eggs, Mr. Koebele was of opinion that we should try and establish the same conditions here. Consequently with the first

cages sent to the plantations the cane cuttings and the cane itself were well sprayed with water containing spores of the fungous disease, so that these would be certainly carried abroad by the emerging hoppers and parasites. I imagine there is no doubt as to this disease becoming established in all suitable localities.

In speaking of the necessity for the continued propagation and distribution of the introduced parasites of the leafhopper, Doctor Perkins reports as follows:[a]

Owing to the manner in which cane is cultivated in these islands, the entomologist working along the lines that have been adopted to control the leaf-hopper pest, meets with a serious obstacle such as is not encountered in dealing with insects injurious to our other vegetation. I refer here to the universal custom of burning off the trash over great acreages, after the crop has been harvested. I have been told that on the Colonial Sugar Refining Company's estates in Australia no such burning off is allowed. If this is correct, it may help to account for the insignificant numbers of our cane-leaf hopper there, as well as of several other insects of the same group, which are fortunately not known in our cane fields. As, however, burning of trash is an established fact here, it becomes necessary to see what steps can be taken to provide against this serious disadvantage. I will first show whereof this disadvantage consists. The parasitic enemies of the leaf-hopper are mostly delicate and minute creatures, not accustomed to take prolonged flights. Their wings serve well to bear them from plant to plant, but for further distribution they are dependent on air-currents. If when a field of cane is cut the wind blows towards another cane field, no doubt some or many parasites will reach it, but if otherwise, probably none will do so. In burning over a field it is quite certain that almost every parasite yet present will be destroyed, but the adult leaf-hoppers on the other hand are well able to take care of themselves. When, as an experiment, a patch of about nine acres of cane, so heavily attacked by leaf-hopper as to be useless, was set on fire all around to destroy these, it was noticed that the adult hoppers rose from the cane in a cloud and spread to other fields; so this plan for destroying them was of no value. I have in an earlier publication shown how quickly the leaf-hoppers spread to new fields of very young cane, and with what regularity they distribute themselves over the young plants. It cannot be hoped that the parasites will (except under rare and fortuitous circumstances, such as constant favorable winds) spread themselves in like manner, and in the same time. Yet it is essential that the parasites should be on the spot when the leaf-hopper *begins to lay* in order to secure proper control. If the supply of laying hoppers at the beginning of the great breeding season is very small, it means that there is not time for the attack to become serious before that season is over. It is when the hopper is least abundant, that one wants to be assured that it is being attacked by all possible enemies. When a field is already seriously injured and swarming with hoppers, not much immediate help can be given for obvious reasons. It will be easier to prevent such a condition than to find a remedy. If one could provide that in each large area of cleared land, ready for planting, there should be in the middle a small patch of some variety of cane most susceptible to the attack of leaf-hoppers, that this cane should be kept well stocked with these, and with a variety of parasites and predaceous insects, and itself be of sufficient growth to afford good shelter to all these, the condition from an entomological standpoint would be ideal. This patch of cane, being already of suitable age and growth and stocked as aforesaid, at the time the much younger cane of the rest of the field began to be infested with hoppers, would

[a] Perkins, R. C. L.—Leaf-hoppers and their natural enemies. <Hawaiian Sugar Planters' Exp. Sta., Div. Ent., Bul. 1, introduction, pp. xviii–xxi, May, 1906.

daily be distributing thousands of natural enemies, that should control these. Although such a plan or modification of it might be adopted on some plantations, on others (at least such as are under irrigation) it would either be difficult, or altogether impracticable. Only in the case of some fields of long ratoons would the matter be very simple, when a small area of the original ratoon growth in each field could be left uncut, and if well supplied with hoppers and their natural enemies would serve later on to stock the rest of the field. Unfortunately, owing to the fact that ratoons are (except in unusual cases) not severely attacked as compared with plant-cane, this matter becomes one of minor importance. Otherwise, in the majority of cases, owing to the clearing of large areas and the burning of trash, it is probable that new fields will have to be supplied by cages similar to those already used. Two things will be absolutely necessary: (1) that the new fields be well supplied with parasites; (2) that they be stocked immediately the hoppers enter them and commence laying. This plan, though less satisfactory than would be the other method, is nevertheless simple, and does not call for much expenditure of time, nor for skilled labor. The one thing necessary to be positively ascertained is that the spot whence the cuttings for distribution are taken is well supplied with *all* the kinds of parasites that it is desired to establish in new fields. It is now well known to us that *all* these destroyers are not yet established *in all parts* of all plantations, and therefore at present unless an entomologist previously test samples from the spot, whence distribution is to be made, it is quite likely that some of the most valuable parasites will not be taken to the new fields. If a sample be submitted to the entomologists, it can be passed as fit to supply all necessary parasites to new fields, or if not, cages of the deficient species can always be supplied from the cane in the grounds of the Experiment Station in Honolulu. As the parasites are continually spreading and increasing, such expert examination will at the most be necessary for a year or two; for it is perfectly certain that by that time all the species will be so general that it will be quite impossible to take any extensive sample of cane-leaves that bear eggs of leaf-hopper, which will not contain all. Such in fact is now the case in the cane at the Experiment Station. To sum up, the clearing of all cane from large acreages is a decided obstacle to the complete success of natural enemies of leaf-hopper, and the burning of trash aggravates the difficulty. As an offset to these conditions new fields should be supplied artificially with natural enemies, and they should be supplied as soon as any leaf-hoppers enter them. Of course future observation may prove this distribution unnecessary, but for the present it should be adopted.

RELATED SPECIES.

The Hawaiian sugar-cane leafhopper *does not occur on the mainland of the United States.* The insect is closely related to the corn leafhopper (*Dicranotropis maidis* Ashm.), common on corn in the Southern States.[a] A West Indian species of leafhopper is recorded as injurious to sugar-cane, by Westwood, in 1841, under the name *Delphax saccharivora* and is a member of the same family of insects as the Hawaiian sugar-cane and the corn leafhoppers.[b] Three further species of this same family, the Fulgoridæ, are recorded as sugar-cane pests in Java by W. van Deventer.[c]

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[a] QUAINTANCE, A. L.—Fla. Agr. Exp. Sta., Bul. 45, 1898.

[b] WESTWOOD, J. O.—Mag. Nat. Hist., vol. 6, p. 407, 1841.

[c] *Phenice maculosa*, *Dicranotropis vastatrix*, and *Eumetopina krügeri*. Van Deventer, Handboek ten dienste van de Suikerriet-cultuur en de Rietsuiker-Fabricage op Java, II. De Dierlijke vijanden van het Suikerriet en hunne Parasieten. Amsterdam, pp. 167–169, 1906.

THE HAWAIIAN SUGAR-CANE BORER.

([*Sphenophorus*] *Rhabdocnemis obscurus* Boisd.)

GENERAL CHARACTERISTICS.

The sugar-cane "borer" ([*Sphenophorus*] *Rhabdocnemis obscurus* Boisd.) (fig. 4), infesting the cane stalk in Hawaii is the grub of a beetle belonging to the weevil family Calandridæ. The sugar-cane stalk-borer of the southern United States is the caterpillar of a moth,

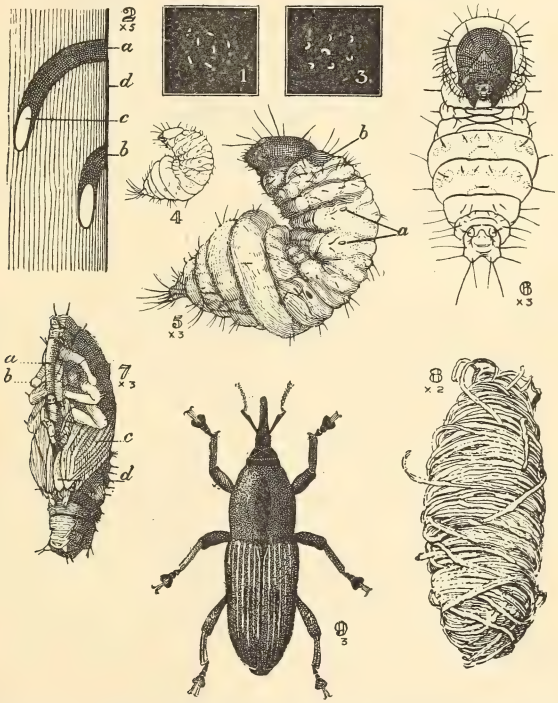

FIG. 4.—The Hawaiian sugar-cane borer ([*Sphenophorus*] *Rhabdocnemis obscurus*): *1*, Eggs, natural size. *2*, Eggs in situ, much enlarged: *a*, Section of egg passage with egg, *c*; *b*, egg placed unusually near the rind, *d*. *3*, Larvæ, just hatched and older, natural size. *4*, Full-grawn larva, natural size. *5*, Larva, side view, enlarged: *a*, Spiracles; *b*, cervical shield. *6*, Larva, front view, enlarged. *7*, Pupa, enlarged; *a*, Rostrum or beak; *b*, antenna; *c*, elytron or wing cover; *d*, folded wing. *8*, Pupal case or cocoon, enlarged. *9*, Adult, enlarged. (After Terry.)

Diatræa saccharalis Fab. Entomologically the two species are widely separated, belonging to entirely different orders of insects, but in the character of their injury to the cane stalk these two insects are quite similar—that is, they both develop within the cane stalk, and

by feeding on the interior cause great destruction to the plant. Comparatively, the Hawaiian borer is more destructive and, because of the habits of the adult, a more persistent species to combat. The adult beetle of the Hawaiian borer is a stronger flyer than the adult moth of the mainland borer and therefore has a wider range over any infested territory. As the adult of the Hawaiian borer, too, can emerge from any reasonable depth when buried in the soil, this renders the question of infested seed cane a serious one in Hawaii, while on the mainland the careful covering of infested seed cane is effective in preventing the emergence of the adult moth. These points are mentioned to bring out the fact that we are discussing here a species in no way related to the cane borer of the Southern States and in many ways not subject to the same means of control.

[*Sphenophorus*] *Metamasius sericeus* Oliv. is a species injurious to cane in the West Indies, being recorded from Jamaica, Barbadoes, St. Kitts, Antigua, St. Lucia, and British Guiana.

In Porto Rico *Sphenophorus sexguttatus* Drury is recorded by Busck[a] as boring in the stalks of sugar cane.

DISTRIBUTION.

The sugar-cane borer of Hawaii is recorded also from Fiji, New Guinea, New Ireland, Tahiti, Queensland, and the Malay Archipelago and probably occurs pretty generally throughout the islands of the southern Pacific.

OCCURRENCE IN HAWAII.

This species is a pest of long standing in the islands. The insect is recorded from the Island of Oahu in 1885 by the Rev. Thomas Blackburn,[b] who found the species breeding in the stems of bananas in the mountains, and the files of the Bureau (then Division) of Entomology, record the receipt of the borer from the Hawaiian Islands, as early as 1888.[c] It is believed that the sugar-cane borer was introduced into the islands from Tahiti in the stems of the banana plant during the early communications between the Hawaiian Islands and those of the South Seas. Hon. H. P. Baldwin, of Puunene, Maui, informed the writer that to his personal knowledge the beetle was injurious to sugar cane in the vicinity of Lahaina, the ancient capital of the islands, as early as 1865.

Aside from the banana plant and sugar cane, the beetle infests the coconut palm, the sago palm, the royal palm, the wine palm, (*Caryota urens*), and the papaia (*Carica papaya*).

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[a] U. S. Dept. Agr., Bur. Ent., Bul. 22, p. 89, 1900.

[b] Blackburn, Rev. T., and Sharp, D.—Memoirs on the Coleoptera of the Hawaiian Islands. <Sci. Trans. Roy. Dublin Soc., 2 ser., vol. 3, pp. 119–290, pl. 1, 1885.

[c] General Notes, Bureau of Entomology, No. 4332b.

Until the recent injury by the leafhopper (*Perkinsiella saccharicida*) the sugar-cane borer was the principal insect affecting cane in the islands.

The species was determined by the Bureau of Entomology at Washington, D. C., in 1888 from specimens forwarded by the late King Kalakaua and was discussed under the title "The Sandwich-Island Sugar-cane Borer," in Insect Life, vol. 1, No. 6, pages 185–189, December, 1888.

In 1896 Mr. Koebele gave the following record on the work of the borer in Hawaii: [a]

> This may be classed as the most injurious enemy of the sugar cane present on these islands. Its ravages will exceed those of all other insects combined. Its attacks on the sugar cane, however, seem confined to the more damp localities, whilst in drier places, such as Lahaina, the borer is hardly noticed. I have been informed that the Lihue Plantation has recently suffered severely from the attacks of the borer. Not only sugar cane is damaged by this insect, but many other plants are damaged by it, chiefly the bananas and cocoanuts. A grove of the latter was shown me in Hilo, in 1894, that was badly infested by the beetles. Setting fire to the dry leaves was recommended; this was done and the plants have since entirely recovered. Dying cocoanut palms were examined and in the tender heart of the palm were found great numbers of the insects, in all stages.

More recently (1907) Mr. F. W. Terry has discussed the sugar-cane borer in the Hawaiian Islands in a circular of the Hawaiian Sugar Planters' Experiment Station. [b]

LIFE HISTORY AND HABITS.

The eggs are found beneath the epidermis of the cane stalk, or more rarely in the tissue of the leaf sheath, having been placed singly in small cavities. The cavity is made by the female with her proboscis before depositing the egg.

The young grub or larva, on hatching from the egg, bores on into the stalk of the cane, completely honeycombing the interior with tunnels running lengthwise with the stalk (see fig. 5). The evidence of its work is not indicated by the outward appearance of the stalk. Many times a stalk, seemingly in a normal condition, is found on examination to be utterly destroyed. The life of the borer within the stalk of the cane is estimated to be about seven weeks by Mr. Koebele, [c] who points out the fact that the length of the larval life

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[a] Koebele, Albert.—Report on insect pests. <Hawaiian Planters' Monthly, vol. 15, no. 12, p. 590, December, 1896.

[b] Terry, F. W.—Hawaiian Sugar Planters' Exp. Sta., Div. Ent., Cir. 3, pp. 22, plates 2, fig. 1, December, 1907.

[c] Koebele, Albert.—Hawaiian Planters' Monthly, vol. 19, no. 11, p. 520, November, 1900.

FIG. 5.—Work of the Hawaiian sugar-cane borer in sugar cane: *a*, *a*, *a*, Emergence holes made by the larva before pupation; *b*, *b*, "rupture" holes, apparently accidental and made by the larva while feeding; *c*, holes made by the female borer for the reception of her eggs; *d*, cocoon; *e*, larva; *f*, *f*, "frass" or undigested cane fiber, passed by the larva. One-half natural size. (After Terry.)

depends to a great extent upon the condition of the food plant and climatic conditions; that is, the development will be more rapid in softer cane and during the warm summer months than during the low temperatures of winter.

When ready to pupate—that is, to transform to the inactive stage preparatory to emerging from the stalk as an adult beetle—the larva (fig. 5, *a*) forms about itself a cocoon (fig. 5, *b*) from the fiber of the stalk within the tunnels it has made in feeding. The adult beetle on issuing from this cocoon bores its way through the side of the stalk to the exterior, and this opening in the lower joints of the cane is the first distinct symptom of the presence of the borer. The length of the pupal period is as variable as that of the larval, the average time for transformation and emergence being from two to three weeks.

The beetles are night flying and hide during the day down within the sheaths of the lower leaves. The softer varieties of cane are more subject to attack than the hardier varieties, and the borer is more abundant in the wet districts than in the dry. Cane which has received an abundant supply of water by irrigation suffers more from the work of the borer than unirrigated cane. The borers occur in the largest numbers in young cane and the suckers are infested to a much greater degree than the stalks. The borers always occur in the largest numbers in the vicinity of the track used to haul cane to the factory, issuing from infested stalks that have dropped from the cars and have not been collected and destroyed afterwards.

The borer is a strong flyer and spreads from field to field in this manner. It is distributed in infested seed cane and also develops from the stalks left in the field after harvest or dropped from the wagons or cars in hauling to the factory.

CONTROL MEASURES.

Selection of Varieties for Planting.

As has been mentioned, the softer varieties are more subject to attack than the hardier ones. The Yellow Caledonia, a variety which is replacing to a great extent the common Lahaina and Rose Bamboo in Hawaii, is injured to a much less extent than other varieties. The infestation is not necessarily less in Yellow Caledonia, but the borer meets with greater resistance in its feeding and consequent development because of the firmness of the fiber.

Irrigation.

Excessive irrigation favors the development of the pest, since cane in a succulent condition is more easily infested by the borer and its development within the stalk is more rapid. It is plain that in fields heavily infested by the borer the minimum amount of water should be used in irrigation.

Burning of Trash.

The burning of trash after harvesting the cane is the most effectual method of keeping the borer in check. In this practice not only should the fields be burned over, but all the unburned stalks left in the fields and all stalks dropped from carts and cars along the roads and tracks used in hauling the cane to the factory should be collected and burned. One plantation found it necessary to collect such stalks in piles and use crude oil on them in order to destroy them completely, and by a careful estimate of the labor and cost of material found that the money had been well invested, as was shown by the reduction in the numbers of borers in the fields the following season.

Selection of Noninfested Seed Cane.

The Hawaiian sugar-cane borer is able to emerge to the surface from any reasonable depth when planted with seed cane. For this reason great care should be exercised in the selection of cane for planting purposes, since new areas can in this way be readily stocked with the pest. It is not practical to treat successfully cane infested with the borer, since the borer is fully protected within the stalk. Therefore, next in importance to the thorough burning of all trash after harvest is the selection of noninfested seed cane.

Picking and Baiting.

The most effective direct measure employed against the cane borer is the collecting of the adults during the daytime from their hiding place within the lower leaf sheaths. The supply of labor will

influence the ability to use this method. The method is more feasible where the plantation is so situated that women and children can be employed for the work. Care should be exercised in this work in order that the growing leaves may not be broken down. It is obvious that a larger number of beetles will be collected when the wages are based on the numbers collected, but the results are more satisfactory, as regards breaking down the cane, when the wages of the laborers are fixed at a certain amount per day.

In the Fiji Islands a method of baiting the beetles is employed, which consists of splitting cane stalks and placing pieces about the edges of the field and within the rows at certain intervals. The method as practiced in Fiji is thus described by Mr. Koebele.[a]

> At the request of the Colonial Sugar Company we looked into the matter with a view of getting rid of the beetles the best way possible; all sorts of devices were employed and none worked better than pieces of split cane about 12 inches long, placed along the edges of the field and through the same at intervals of 12–18 feet; thus with seven little Indian girls, I collected over 16,000 beetles in some four hours, and the same little girls alone brought in the following noon over 26,000 beetles.
>
> This method was kept up, and followed on all the plantations for the next three years, or until no more of the borers could be found. Tons of the same were brought in at the Nausori mill alone, and the expenses of collecting were practically nothing compared to the cost at Lihue, where such work has to be done by the day laborers. About four cents per pint of the insects was paid to the children. The result has been highly satisfactory, for, ever since the last five years, the cane borer has not been a pest in those islands.

An important point regarding this split cane is that the females usually infest these pieces heavily with eggs and the young resulting grubs bore into the split stalks and perish as the pieces of cane become dry. In dry localities the pieces of split cane should be placed in the irrigation ditches during the day and placed out as bait in the evening, otherwise they dry out rapidly and cease to attract the beetles.

RELATED SPECIES.

The Hawaiian sugar-cane borer is represented in the United States by the "corn bill-bugs," of the genus Sphenophorus, several species of which in the adult stage attack the leaves of corn, but rarely breed in the stalk of corn as does the Hawaiian Sphenophorus in the stalk of cane. *The Hawaiian cane borer does not occur on the mainland of the United States.*

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[a] KOEBELE, ALBERT.—Hawaiian Planters' Monthly, vol. 19, no. 11, p. 522, November, 1900.

THE HAWAIIAN SUGAR-CANE LEAF-ROLLER.

(*Omiodes accepta* Butl.) (Plate III.)

EARLY HISTORY IN THE HAWAIIAN ISLANDS.

During the investigations relating to the leafhopper in 1903 the writer found the Hawaiian sugar-cane leaf-roller, the caterpillar of a native moth, doing serious damage to cane in the upper fields of plantations in the Kohala district, Island of Hawaii. The larvæ were collected also from Hilo grass (*Paspalum conjugatum*) growing wild above the cane areas. The species, primarily a grass feeder, occurs in the higher altitudes and invades the bordering fields from these locations. It is recorded by Meyrick [a] in 1899 from the islands of Hawaii, Maui, Molokai, and Kauai at elevations ranging from 1,500 to 5,000 feet. The caterpillar was described for the first time by Dr. H. G. Dyar, of the United States National Museum, from specimens collected by the writer on cane in the Kohala district. [b]

Swezey states that the leaf-roller occurs on practically all of the plantations of the islands, but is less abundant in the dry districts. Regarding its injury he says: [c]

> It is present in some fields of cane sometimes in such large numbers as to do considerable damage; in fact, cases have been reported where the young cane has been entirely stripped of leaves. Such instances are not numerous, however, and even in the worst cases would not result in entire destruction of the crop of cane as it would grow again after the caterpillars had obtained their growth, or their parasites had got them checked. It is not usually to be considered a serious pest. Possibly it is not so abundant now as it was a few years ago when reports were made of cane fields having been entirely stripped by them.
>
> At present there are a number of parasites preying upon this species and this keeps them well in check.

In this same report, page 10, the author describes the habits of the caterpillar as follows:

> On sugar cane the very young larvæ feed in the crown of the plant where the young leaves have not yet unrolled. They are thus protected between the natural rolls of the leaf; later on they roll over the margin of a leaf forming a tube for their "retreat." When nearly full grown, they are usually found in tubes towards the tip of the upper leaves. These tubes are easily observed if the ragged leaves where the larvæ have fed, are examined. The work of the smaller larvæ shows as oval or elongate dead spots on leaves which have unrolled in the growing of the cane after the young larvæ have fed upon them.
>
> When disturbed in its retreat, as by its being torn open, or violently shaken, or jarred, the larva wriggles verylively and drops to the ground for escape. This habit is

---

[a] Meyrick, E.—Fauna Hawaiiensis, vol. 1, Pt. II, p. 204, 1899.

[b] Dyar, H. G.—Note on the larva of an Hawaiian pyralid (*Omiodes accepta* Butler). <Proc. Ent. Soc. Wash., vol. 6, no. 2, p. 65, 1904.

[c] Swezey, Otto H.—The sugar-cane leaf-roller, *Omiodes accepta*. <Hawaiian Sugar Planters' Exp. Sta., Div. Ent., Bul. 5, p. 7, August, 1907.

probably to escape from parasites, many of which prey upon them. The retreat which it constructs is undoubtedly for the same purpose, as well as for protection from wasps and birds which prey upon it.

The caterpillars are full grown in about three weeks from hatching. They molt five times at intervals of about three to five days, and five to seven days between the fifth molt and the spinning of the cocoon and pupation. Pupation takes place within a slight cocoon of white silk in the "retreat" where the caterpillar has lived; however, the cocoon is sometimes made beneath the leaf-sheaths of cane, and in other favorable places.

CONTROL MEASURES.

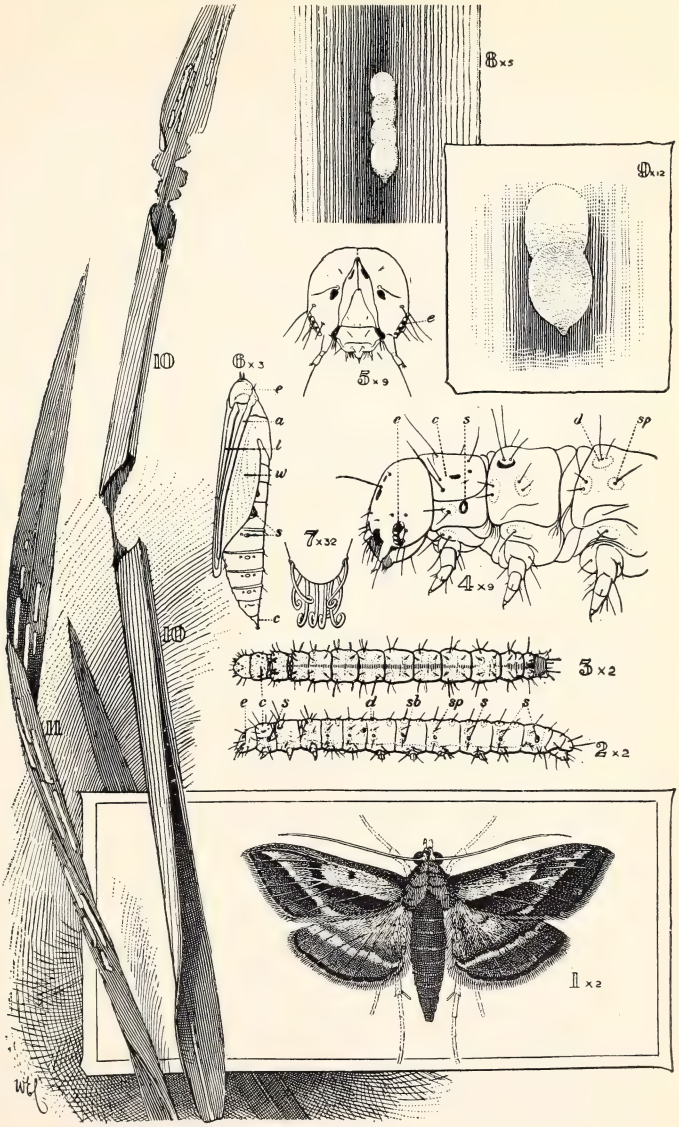
No special remedies are employed in cane fields against this pest. Swezey suggests that in fields of young cane a spray of Paris green or arsenate of lead might be used with effect, and mentions that at times laborers have been sent over the field to pinch the caterpillars in their retreat between the folded cane leaves.

PARASITES.

The species is attacked, fortunately, by several introduced parasites. Regarding the natural enemies of the species of moths belonging to the genus Omiodes, Mr. Swezey reports as follows on pages 36 and 37 in his article above referred to:

Omiodes caterpillars are attacked by a large number of species of parasites, some of which are native, and several which are the most valuable have been introduced. The most of the species are kept in check by their natural enemies, so that they do not become very numerous; in fact, several of them are very rare. Two species feed so numerously on cultivated plants that they become serious pests; *accepta* on sugar cane, and *blackburni* on palms. These two species are preyed upon very extensively by the parasites and checked considerably, but not sufficiently to keep them from doing considerable injury in certain localities and at certain seasons. Apparently the moths are more prolific in the winter months (about December to March) and the parasites are scarcer owing to their having had fewer caterpillars for them to keep breeding on during the preceding summer. Hence, when the winter broods of caterpillars appear, there may be two or three generations of them before the parasites breed up to sufficient numbers so that they produce any noticeable check on the number of the caterpillars; then in another generation or two the caterpillars may be much reduced in numbers and a large percentage of them found to be parasitized; for example, on one occasion 75 % of the cane leaf-rollers in a field at Hutchinson plantation, Hawaii, were found to be destroyed by one species of parasite; at Olaa plantation, Hawaii, in a certain field, on one occasion a much higher percentage of them than that were killed; in Honolulu, of a large number of the palm leaf-roller caterpillars collected, 90 % were parasitized.

Since there are so many species of parasites preying on the leaf-rollers which are pests, it might be asked "Why do they not become exterminated, or at least cease to be pests?" Apparently, with all of the parasites, they are still not numerous enough to overbalance the prolificness of the pest, even though they do kill such high percentages of them at times. Since so many are killed by parasites, and yet there are enough left to do considerable injury at times, one cannot help but wonder to what extent these pests might increase were there no parasites preying on them, and how many times more serious would be the damage done by them. The extreme difficulty and impracticability of treating sugar cane fields, or large palm trees, artificially, for



THE HAWAIIAN SUGAR-CANE LEAF-ROLLER (OMIODES ACCEPTA).

Fig. 1.—Adult moth. Figs. 2, 3, 4, 5.—Larvæ and details. Fig. 6.—Pupa. Fig. 7.—Apex of cremaster, showing the curled spines by which the pupa is fastened to the cocoon. Fig. 8.—Cluster of 4 eggs in groove on surface of leaf. Fig. 9.—Eggs more highly enlarged. Fig. 10.—Leaf spun together for "retreat" or hiding place of caterpillar; showing where caterpillar has eaten. Fig. 11.—Leaf, showing spots where very young caterpillar has eaten, leaving one epidermis intact, instead of eating holes through the leaf. (After Swezey.)

the destruction of these pests, makes it all the more important that there are so many valuable parasites preying upon them; and shows the value of introducing natural enemies to control a pest, for the four best parasites of these leaf-rollers are introduced species, viz., *Macrodyctium omiodivorum, Chalcis obscurata, Frontina archippivora* and *Trichogramma pretiosa.*

THE SUGAR-CANE MEALY-BUG.

(*Pseudococcus calceolariæ* Mask.) (Plate IV.)

IDENTITY.

This insect (see Pl. IV, from photographs by Mr. T. C. Barber) is identical with the sugar-cane mealy-bug common on cane in the southern parishes of Louisiana. The species is recorded by Mrs. Maria E. Fernald from Australia, Hawaii, Fiji, Jamaica, and Florida.[a] Koebele earlier records this mealy-bug on cane in Hawaii.[b]

RELATED SPECIES.

The mealy-bug of the cane belongs to a very large family of insects, Coccidæ, which are world-wide in their distribution. Two other species of this family, *Pseudococcus sacchari* Ckll. and *Aspidiotus cyanophylli* Sign., have recently been recorded from Hawaii by Mr. J. Kotinsky.[c]

Three species, namely, *Pseudococcus calceolariæ, P. sacchari,* and *Aspidiotus sacchari* Ckll., are known to attack sugar cane in the West Indies.[d]

Van Deventer records several scale insects, among them *Lecanium krugeri* Zehntn., *Aspidiotus saccharicaulis* Zehntn., *Chionaspis* spp., and a species of Pseudococcus very similar to *P. calceolariæ,* on cane in Java.[e]

In Mauritius two species of related insects, *Icerya seychellarum* Westw. and *Pulvinaria iceryi* Guér., are reported as pests of sugar cane.[f]

FOOD PLANTS.

Mrs. Fernald gives the food plants of the sugar-cane mealy-bug as *Calceolaria, Danthonia, Phormium tenax, Cordyline australis,* and

---

[a] Fernald, Mrs. Maria E.—A Catalogue of the Coccidæ of the World. <Bul. 88, Hatch Exp. Sta., Mass. Agr. Coll., p. 98, 1903.

[b] Koebele, Albert.—Hawaiian Planters' Monthly, vol. 15, no. 12, p. 596, December, 1896; vol. 17, no. 5, p. 209, May, 1898.

[c] Kotinsky, Jacob.—Coccidæ not hitherto recorded from these islands. <Proc. Hawaiian Ent. Soc., vol. 2, no. 3, pp. 127–131, 1910.

[d] Ballou, H. A.—Review of the insect pests affecting the sugar cane. <West Indian Bul., vol. 6, no. 1, p. 41, 1905.

[e] Deventer, W. van.—Handboek ten dienste van de Suikerriet-cultuur en de Rietsuiker-Fabricage op Java. II. De Dierlijke vijanden van het Suikerriet en hunne Parasieten, Amsterdam, pp. 227–266, 1906.

[f] Fernald, Mrs. Maria E.—A Catalogue of the Coccidæ of the World. <Hatch Exp. Sta. Mass. Agr. Coll., Bul. 88, pp. 27, 133, 1903.

sugar cane. In Louisiana the mealy-bug infests, aside from sugar cane, the Johnson grass (*Sorghum halepense*) and the saccharine sorghums.

LIFE HISTORY AND HABITS.

The feeding habits of the mealy-bug are similar to those of the cane leafhopper; that is, their mouthparts are formed for piercing the epidermis of the plant and sucking the plant sap from the inner tissues. The distinction in the feeding habit is that the leafhopper is active throughout its entire life cycle, and jumps or flies from plant to plant, while the mealy-bug when partly grown remains practically stationary and feeds upon but one portion of the same plant.

Where the cane mealy-bugs occur in Hawaii, they can be found about the lower leaves of the cane, congregating for the most part behind the older leaves near the ground. The species may be recognized by the white mealylike covering of the adult female, to which the common name applies. The insects occur in a mass and when abundant are readily observable by the white covering of the females. This white covering serves as a receptacle for the eggs, which, upon close examination, may be observed embedded therein.

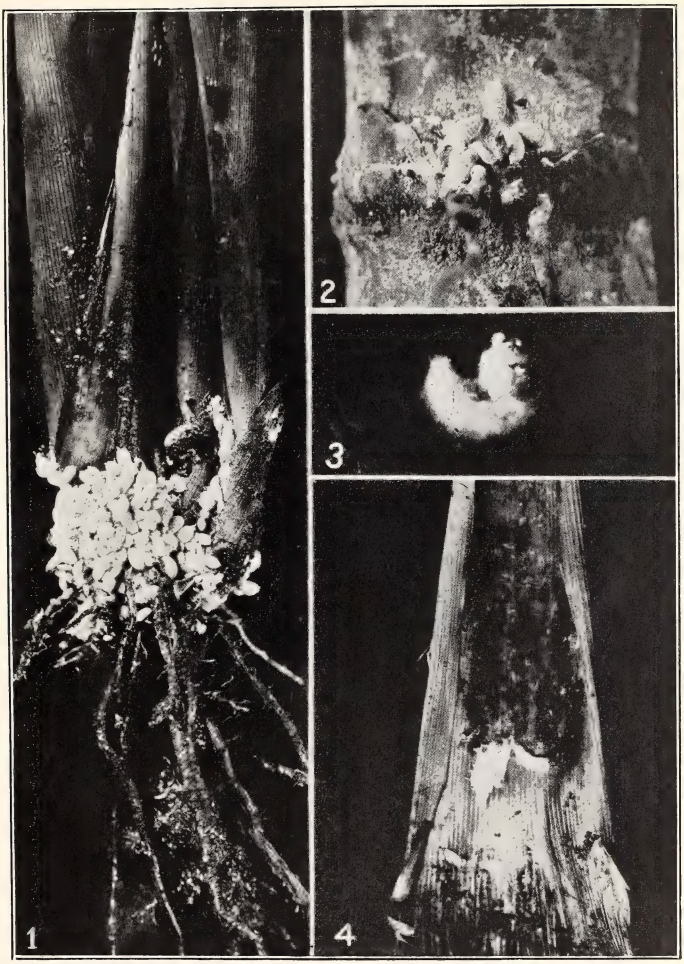
In Louisiana the insects occur not only about the lower leaves of the plant, but are to be found also around the crown (Plate IV, fig. 1) and beneath the surface of the ground about the roots of the plant. In this latter location they hibernate during the cold months of winter on both cane and Johnson grass.

The young mealy-bugs upon hatching from the eggs are quite active and disperse over the cane plants, finally congregating when partly grown about the lower nodes of the stalk. The females are practically inactive, remaining in a mass about one of the nodes or beneath the leaves throughout their development and secreting about themselves in these locations the characteristic white covering (Plate IV, fig. 3). The young males do not remain stationary on the plant, but, after completing their development, spin a narrow white cocoon (Plate IV, fig. 4) within which they transform to a delicate winged adult.

CONTROL.

Selection of seed cane.—Since the common method of distribution is by the transportation of infested seed cane from plantation to plantation or from one part to another of the same plantation, care should be exercised to select clean stalks and not those which are infested, for seed cane.

Burning of the trash.—The practice of burning the trash after harvest is very effective in destroying this insect, since those remain-



THE SUGAR-CANE MEALY-BUG (PSEUDOCOCCUS CALCEOLARIÆ).

Fig. 1.—Adult mealy-bugs clustered about the base of young cane. Fig. 2.—Adult female, twice natural size. Fig. 3.—A single adult female, with white mealy-like covering. Fig. 4.—Cocoons of male mealy-bug. (Original.)

ing on the stalks are killed in the process of milling, and the remaining forms on the discarded stalks and leaves in the field are destroyed by the fire.

NATURAL ENEMIES.

There is present in Hawaii a ladybird beetle, *Cryptolæmus montrouzieri* Muls., which is a special mealy-bug feeder. This ladybird is one of Mr. Koebele's introductions from Australia. It has proved particularly beneficial in feeding upon the sugar-cane mealy-bug in the Hawaiian cane fields, and through its work the numbers of the mealy-bug have been greatly reduced in recent years. This important predator has been established in California, and the Bureau of Entomology at Washington, D. C., has under way at present negotiations to import this beetle into the cane fields of southern Louisiana which are infested by the mealy-bug.

The ladybird is thus described by Prof. W. W. Froggatt, government entomologist of New South Wales.[a]

This beetle is very variable in size, measuring from under 2 to 3 lines in length, with the head, thorax, extreme tip of both wing covers light orange-yellow; the whole of the under surface reddish-brown, and both the upper and under surface clothed with fine hairs. In a number of specimens the under surface is variable in coloration, the middle and hind pairs of legs with the thorax dark reddish-brown to black.

The larva is of the usual smoky-brown tint, but so thickly clothed on the upper surface with white filaments that it appears to be of a uniform white, the pupa hidden beneath the larval skin and the immature beetle are pale yellow.

MISCELLANEOUS INSECTS AFFECTING SUGAR CANE IN HAWAII.

An aphis, *Aphis sacchari* Zehntn., is occasionally injurious to sugar cane. Koebele records an outbreak of the species on the Island of Kauai in 1896 under the name *Aphis* sp.[b] The species was determined by Kirkaldy in 1907.[c] This insect is known to occur on cane in Java. In Hawaii, the species is fed upon by the ladybird *Coccinella repanda* Thunb., though the benefit from this beetle is offset by the work of its braconid parasite, *Centistes americana* Riley.

In some districts where the cane fields are situated in moist locations, a mole cricket, *Gryllotalpa africana* Beauv., is sometimes abundant enough to be injurious. Another species of mole cricket, *Scapteriscus didactylus* Latr., is a most important pest of sugar cane

[a] Froggatt, W. W.—Australian ladybird beetles. <Agr. Gazette of New South Wales, vol. 13, pt. 9, pp. 907, 908, September, 1902.

[b] Koebele, Albert.—Hawaiian Planters' Monthly, vol. 15, no. 12, pp. 596–598, December, 1896.

[c] Kirkaldy, G. W.—On some peregrine Aphidæ in Oahu. <Proc. Hawaiian Ent. Soc., vol. 1, pt. 3, pp. 99, 100, July, 1907.

in the island of Porto Rico.[a] Regarding the work of the Hawaiian mole cricket, Prof. Koebele reports as follows:[b]

A species of mole cricket has appeared in very large numbers in some of the moist valleys on Oahu, it is likely another Asiatic introduction, as a rule these crickets are found around the muddy borders of shallow ponds and watercourses where they live in burrows resembling those of moles, and like that animal their food consists chiefly of earth worms and the larva of various insects. The opinions as to its habits are as yet divided; whilst some authorities claim that it is beneficial, others place it amongst the injurious insects.

Specimens kept in confinement here with pieces of sugar cane would hardly touch them, yet they readily devoured a large number of the larva of the Adoretus or Japanese beetle, as well as those aphodius and a number of earth worms, all within 24 hours.

The ground infested by these crickets was examined and found to be very wet and completely riddled with the burrows down to a depth of three and even four feet, as many as three and four specimens were brought to light in a single shovel full of the soil. In such localities there is no question as to the injurious effects of the crickets on young cane plants, wherever they were numerous almost all of the seed cane was destroyed; they would burrow into the seed from all sides, destroying all the eyes, where the plants had made a growth of a couple of feet the cricket would burrow in below the ground and eat to the center, killing the plant. This is the only instance so far observed of the depredations of these crickets here. In rice and taro fields no damage has been observed as yet, and the only damage that is likely to occur to cane is when it is planted in wet swampy land, as the cricket can only live and thrive in such places, and is not found in ordinary arable land; even in the swamp where the cricket was very numerous, it did not attack the old cane but paid its attention solely to the newly planted seed and very young plants.

This cricket, although living in marshy land, cannot live under water, yet it is a good swimmer; the only remedy that can be recommended at present is to flood the land with water and collect the crickets as they come to the surface, destroying them by placing them in a vessel containing kerosene and water.

The fungoid so contagious to many insects and larva here, does not seem to have any effect on this lively cricket, nor will he have anything to do with poison given in the style of bran, sugar and arsenic.

Certain army worms and cutworms, among them *Heliophila unipuncta* Haw., *Agrotis ypsilon* Rott., and *Spodoptera mauritia* Boisd., are occasionally known to strip fields of young cane. These species and related forms, together with their natural enemies, are discussed in a recent report by Mr. O. H. Swezey.[c]

A bud moth, *Ereunetis flavistriata* Wlsm., is found generally throughout the Hawaiian cane fields and at times is quite numerous. Regarding its injury Swezey says:[d]

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[a] Barrett, O. W.—The changa or mole cricket in Porto Rico. <Porto Rico Agr. Exp. Sta., Bul. 2, pp. 19, fig. 1, 1902.

[b] Koebele, Albert.—Hawaiian Planters' Monthly, vol. 15, no. 12, pp. 594–596, December, 1896.

[c] Swezey, O. H.—Army worms and cutworms on sugar cane in the Hawaiian Islands. <Hawaiian Sugar Planters' Exp. Sta., Div. Ent., Bul. 7, pp. 32, pls. 3, November, 1909.

[d] Swezey, O. H.—The Hawaiian sugar cane bud moth (*Ereunetis flavistriata*) with an account of some allied species and natural enemies. <Hawaiian Sugar Planters' Exp. Sta., Div. Ent., Bul. 6, pp. 40, pls. 4, October, 1909.

It is usually not particularly injurious as it customarily feeds on the dead and drying tissues of the leaf-sheaths of sugar cane; but when very numerous and on particularly soft varieties of cane the caterpillars do considerable eating of the epidermis, and also eat into the buds and destroy them, occasioning a good deal of loss where the cane is desired for cuttings to plant.

The grasshoppers *Xiphidium varipenne* Swezey and *Oxya velox* Fab. feed to some extent on the leaves of cane. The former species is also predatory in habit, attacking the young leafhoppers and the larvæ of the sugar-cane leaf-roller.

Two species of beetles which occasionally invade the cane fields from their common food plants and attack the leaves of the sugar cane are Fuller's rose beetle, *Aramigus fulleri* Horn,[a] and the Japanese beetle, *Adoretus tenuimaculatus* Waterh.[b]

RATS INJURING GROWING SUGAR CANE IN HAWAII.

The so-called roof-rat (*Mus alexandrinus*) in former years was very common in the cane fields of Hawaii and did considerable damage by eating the stalks. This is also the cane-field rat of the island of Jamaica. The species in Hawaii lives now for the most part in trees and the upper stories of dwellings, since it has been driven to a great degree from the cane fields by the introduced mongoose. The introduction of the mongoose was a benefit as regards its destruction to the rats in the cane fields, but the animal is an undesirable acquisition to the fauna of the islands for the reason that in recent years it has included in its dietary the eggs and young of ground-nesting birds and domestic fowls. The destruction of the ground-nesting birds is most regrettable.

---

[a] Van Dine, D. L.—Hawaii Exp. Sta., Press Bul. 14, p. 5, October, 1905.

[b] Koebele, Albert.—Hawaiian Planters' Monthly, vol. 17, no. 6, pp. 260–264, June, 1898.

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